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Emissions from Refinery Process Heaters Equipped with Low-NOx Burners

KVB, Inc.
Irvine, CA

Prepared for

Industrial Environmental Research Lab.
Research Triangle Park, NC

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Prepared for

Office of Air Quality Planning and Standards

Prepared by

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

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16. ABSTRACT The report summarizes an investigation of the performance of commercial low-NOx burners in refinery process heaters. Refineries in Southern and Central California were surveyed to determine the number of existing or planned low-NOx burners. Tests on 10 process heaters equipped with low NOx burners measured gaseous emissions, particulates, and efficiencies at normal operating conditions. As-found NOx emissions increased from 58 to 245 ng/J as fuel-bound nitrogen increased from zero to 0.81 %. In most cases, NOx concentrations were strongly influenced by excess air levels. Reducing excess air to 3-4 % reduced NOx to 34-200 ng/J, depending on fuel nitrogen. Comparisons of present emissions data with past field test data for refinery heaters equipped with standard burners showed that (for mechanical-draft gas-fired heaters) low-NOx burners may reduce the NOx emission factor by 32-77 % below the mean emission factor for standard burners. Three heaters (one firing gas; one, distillate oil; and one, residual oil) were selected as the most suitable candidates for 30-day continuous monitoring of gaseous emissions.

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EMISSIONS FROM REFINERY PROCESS HEATERS EQUIPPED WITH LOW NOx BURNERS

by

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ABSTRACT

This final report summarizes the results of a program to investigate the performance of commercial low-NO_x burners in refinery process heaters. A survey of refineries located in Southern and Central California was conducted to determine the number of low-NO_x burner installations existing or planned. Tests were conducted on ten process heaters equipped with low-NO_x burners to measure gaseous emissions, particulates, and efficiencies over a normal range of operating conditions. The as-found NO_x emission increased from 58 to 245 ng/J as the fuel-bound nitrogen increased from 0 to 0.81 percent. The NO_x concentrations were strongly influenced by excess air levels in most cases. Reducing excess air to 3-4 percent reduced NO_x to 34 - 200 ng/J depending upon fuel nitrogen. Comparisons of present emissions data with past field test data for refinery heaters equipped with standard burners showed that for mechanical draft, gas-fired heaters, low-NO_x burners may reduce the NO_x emission factor by 32 percent to 77 percent below the mean emission factor for standard burners. Three separate heaters, one firing gas, another firing distillate oil, and the third firing residual oil have been selected as the most suitable candidates for 30-day continuous monitoring of gaseous emissions.

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LIMITATIONS ON APPLICATION OF DATA REPORTED

The pollutant emission data cited in this report represent a small sample of industrial combustion equipment. The data are intended to present the general emission characteristics of each type of equipment tested and the response of that equipment to combustion modifications. Because of the small sample size, application of the data to estimate mean emissions from a class of similar equipment, or to predict emissions from any other single piece of equipment, or for use in establishing emissions standards would be a misapplication. Mention in this report of trade names does not constitute endorsement by the United States Environmental Protection Agency.

SECTION 1.0

INTRODUCTION AND SUMMARY

It has been estimated that there are approximately 6000 refinery process heaters now in operation in the United States (Ref. 1). Of these, about 5400 have natural draft type burners and the remainder have forced or balanced draft burners. Both types emit a total of about 121.5 Gg/y (134,000 tons/y) of NO_x making process heaters one of the largest industrial emitters of this pollutant.

Several field test programs have been conducted in order to characterize the NO_x emissions from process heaters over a wide range of operating conditions. However, all of the previous field test work was conducted on heaters equipped with conventional burners. It is only recently that refinery heater burner manufacturers have begun to market low-NO_x burners for the petroleum industry and new commercial installations are somewhat sparse.

It was the purpose of this program to (1) locate refineries in Southern California which have installed or ordered low-NO_x burners, (2) test nine gas- or oil-fired process heaters in which low-NO_x burners have been installed (NO_x and other gaseous emissions were to be measured over a normal range of operating conditions), and (3) assess the potential for long term (30-day) tests of each of the nine heaters with the goal of finding three suitable sites--one firing gas, a second firing distillate oil, and the third firing residual oil.

Southern California was selected as the region in which to conduct the heater survey because of its strict NO_x emission regulations, hence, the likelihood of finding installations having low-NO_x burners. The results of the survey are summarized in Table 1-1. At least 26 heaters with low-NO_x burners installed or planned for installation were found. Those heaters which were tested in this program are labelled by site number in the "comment" section of Table 1-1. The results of the tests conducted at these ten sites are reported in the following sections. (Site 10 was added to the required nine test sites

TABLE 1-1. HEATER LOW-NO_x BURNER TEST SITE SURVEY

Location	Site No.	Air Quality Control Region	No. Heaters	Heat Input Rate		Burners	Operational	Fuel	Comments
				MW	10^6 Btu/Hr				
A	2	31	1	4.7	~16	1	Yes	LO-S resid	Natural Draft
B	-	31	1	16.4	56	8	Yes	6 Gas, 2 Oil	Old heater; leaks above firebox
C	-	24	-	-	-	-	-	-	
D	-	24	-	-	-	-	-	-	
E	-	24	1	7.5	25.7	4	Dec 80-Jan 81	Gas	Natural Draft
F	-	31	11	-	-	-	-	-	
G/1	6, 7, 8, 9	30	4	93.8[1]	320	32	Sept. 80	Gas	Preheat, Balanced Draft
G/2	10	30	1	8.8	30	1	Sept. 80	Gas	Ambient, Forced Draft
H	-	24	1	7.7	26.4	8	Jan. 81	-	
I	-	31	1	10.3	35	3	March 81	#6 Oil	Natural Draft
J/1	-	24	1	-	-	-	Jan. 81	Gas	Natural Draft
J/2	-	24	1	-	-	-	Jan. 81	Gas	Natural Draft
K	1	24	1	6.1-6.7	21-23	3	Yes	Gas	Forced Draft
L/1	4	31	1	6.7	22.9	3	Yes	#5 Oil, gas	Natural Draft
L/2	3	31	1	11.7	39.9	12	Yes	#5 Oil, gas	Natural Draft
M	5	31	1	11.7	40	10	Yes	#6 +RG	Natural Draft
N	-	24	-	-	-	-	-	-	
O/1	-	30	1	21.4	73	-	Yes	Gas	Natural Draft
O/2	-	30	1	6.4	22	-	Yes	Gas	Natural Draft
P	-	31	-	-	-	-	-	-	

[1] Total for four heaters.

because of its close proximity to Sites 6 through 9 and the willingness of the refinery to allow the unit to be tested.)

1.1 SUMMARY OF PROGRAM RESULTS AND COMPARISON WITH PAST RESULTS

This program required that baseline tests be conducted for nine refinery process heaters equipped with low-NO_x burners. Tests were completed on ten process heaters.

At each test site, the gaseous emissions and stack gas temperature were measured. Samples of the fuel were taken and submitted to an independent laboratory for analysis. Unit operational data such as flow rates, pressures, temperature, etc., were recorded on a periodic basis. After testing the unit in the as found condition, burner registers and/or stack dampers were adjusted to determine the effect of excess oxygen on unit operation, gaseous emissions, and heater efficiency.

The heaters tested under this task included four natural draft and six mechanical draft units firing gas, distillate and residual oils. Four of the mechanical draft units had preheated combustion air.

1.1.1 Results

Figure 1-1a shows NO_x emissions in ppm by volume as a function of stack oxygen for the ten process heaters tested. These data show that for all cases, lowering the oxygen resulted in lower NO_x emissions. The gas-fired heaters had lower NO_x emissions than did the distillate-oil-fired heater, and the residual-oil-fired heaters had the highest NO_x emissions. The gas-fired heaters with combustion air preheat had higher NO_x emissions than gas-fired heaters with ambient combustion air. Figure 1-1b is a plot of the NO emission factor as a function of stack oxygen for the ten heaters. The points at which significant CO emission or visible smoke occurred are marked in the figure as "CO limits."

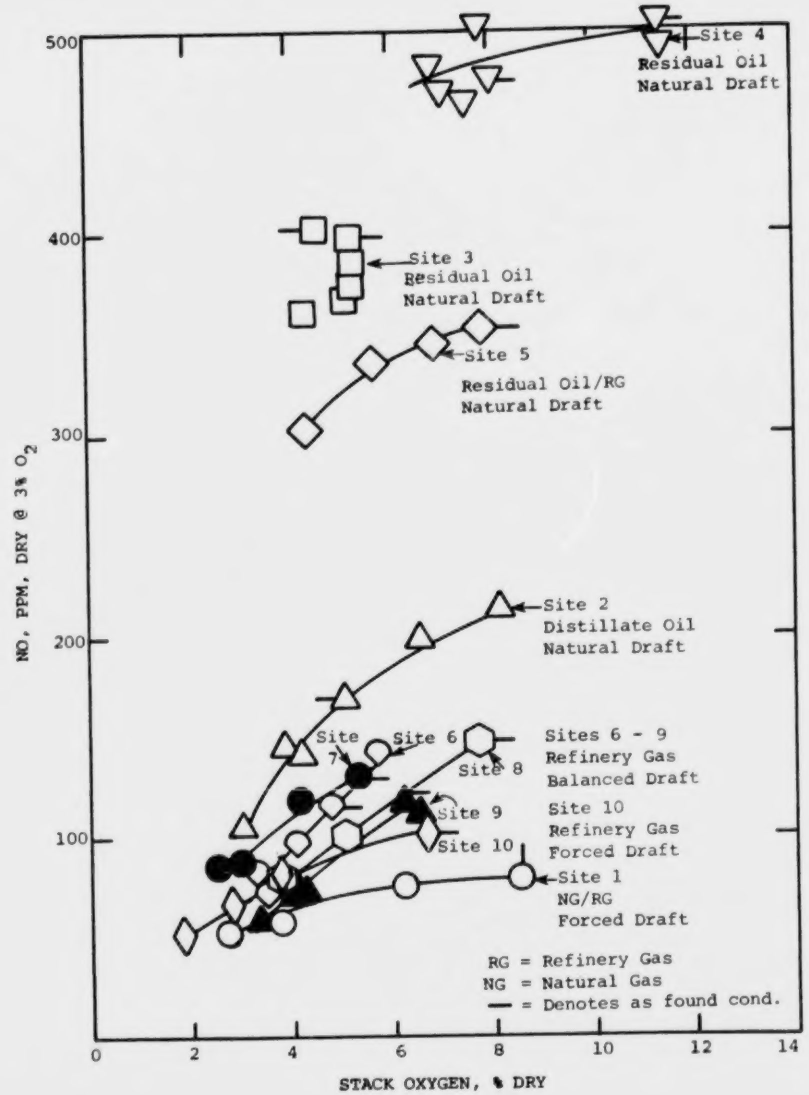

Figure 1-1a. NO_x emissions as a function of stack oxygen for low-NO_x burners in process heaters.

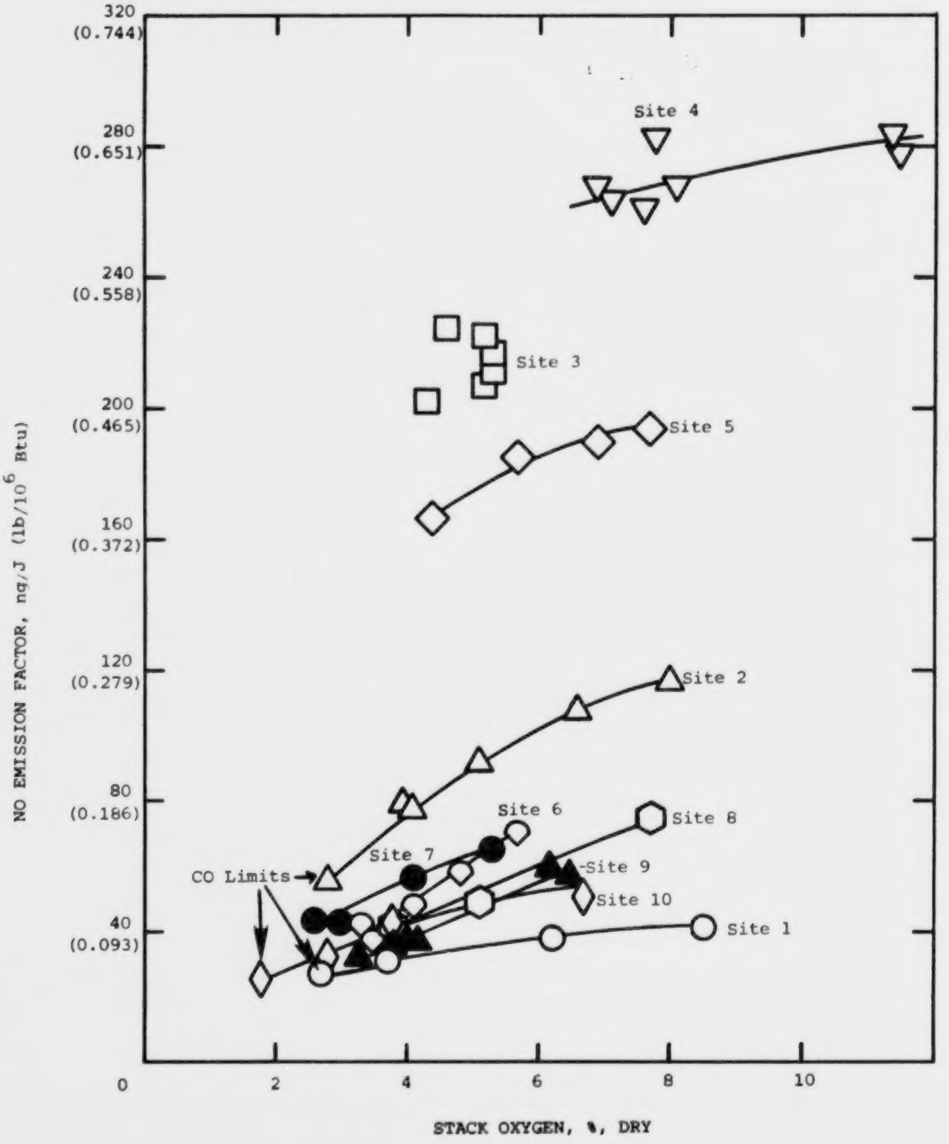

Figure 1-1b. NO emission factor for 10 process heaters equipped with low-NO_x burners as a function of stack oxygen.

Gas-fired heaters with ambient combustion air showed NO_x emissions in the 40-50 ng/J (80-100 ppm at 3 percent, O_2, dry*) range in the "as found" condition. By lowering the excess oxygen to a CO limit or to the minimum acceptable operating condition as determined by the plant, NO_x emissions were reduced to approximately 25 ng/J (50 ppm). Heaters with preheated combustion air showed "as found" NO_x emissions in the 58 to 76 ng/J (115 to 150 ppm) range. Lowering excess oxygen resulted in NO_x reduction to a 25-43 ng/J (50-85 ppm) range.

"As found" NO emissions from a natural draft distillate-oil-fired process heater were 92-117 ng/J (168-212 ppm) and were reduced to approximately 58 ng/J (105 ppm) by lowering excess air to the single burner.

Emissions in the "as found" condition were considerably higher for the three units firing residual oil. All were natural draft units and two of them were found to be emitting 207-281 ng/J (370-500 ppm) of NO. The unit at Site 5 fired 15 to 20 percent refinery gas simultaneously with the residual oil. This unit was found to be emitting 194-205 ng/J (350-370 ppm) of NO and was the only unit firing residual oil which showed a significant tendency toward reduced emissions when excess air levels were lowered. At reduced excess air settings this unit produced about 166 ng/J (300 ppm) of NO.

Table 1-2 is a summary of gaseous emissions and efficiency for each site tested in the present study. A comparison of emissions at as found conditions and at optimum low-NO_x conditions (i.e., lowest NO_x emission without adverse effects on flame stability or unit efficiency) is made in this table. At most sites significant reductions in NO_x emission below as found levels could be achieved along with small increases or, at worst, no change, in efficiency. With respect to flame stability, product flows and temperatures, and emissions of CO and unburned hydrocarbons, unit operations at the optimum low-NO_x conditions were generally unchanged from the as found conditions.

---

*All emission concentrations given as ppm are corrected to 3 percent O_2, dry basis.

TABLE 1-2. OPTIMUM LOW-NO_x AND AS-FOUND GASEOUS EMISSIONS AND EFFICIENCIES AT TEN HEATERS EQUIPPED WITH LOW-NO_x BURNERS

			As Found					Optimum Low-NO_x				
Site	Heater[†] Config.	Test Nos. (A.F.; Low-NO_x)	NO (ng/J)	NO (ppm)	O_2 (%)	CO (ppm)*	Htr. Eff. (%)	NO (ng/J)	NO (ppm)	O_2 (%)	CO (ppm)*	Htr. Eff. (%)
1	121	1-13;1-24	39.0	77	6.2	0	79.9	24.0	48	3.0	20	83.0
2	211	2/1-1e;2/1-3a	92.4	168	5.1	11	64.0	80.4	145	4.0	11	64.0
3	311	3-1;3-3	222.0	396	5.2	11	63.4	203.0	361	4.3	11	64.5
4	311	4-1;4-4	268.0	477	8.1	0	67.9	264.0	471	7.1	0	68.6
5	411	5-3/5-6	194.0	352	7.7	11	---	167.0	303	4.4	22	---
6	132	6/5-3;6/5-1	57.9	114	4.8	11	69.8	38.1	75	3.5	11	71.3
7	132	7/1-1;7/2-2	65.8	130	5.3	11	68.0	35.4	70	2.3	33	68.5
8	132	8/1-1;8/1-3	74.9	148	7.7	14	65.4	41.0	81	3.8	15	69.2
9	132	9/1-1;9/1-3	60.2	119	8.4	0	66.4	32.9	65	3.3	10	68.8
10	121	10/1-1;10/1-4	51.6	102	6.7	13	73.1	32.9	65	2.8	10	74.4

*Dry, corrected to 3% O_2.

†Heater configuration designations as follows:

1st Digit	2nd Digit	3rd Digit
Fuel burned	Draft type	Air temp.
1 = gas	1 = natural	1 = ambient
2 = dist. oil	2 = forced	2 = preheater
3 = residual oil	3 = balanced	
4 = combined oil & gas		

Figure 1-2 is a plot of the effect of fuel-bound nitrogen content on the NO_x emission factor. The three circles plotted in this figure represent the data from units tested in the present program which fired oil fuel. Site 2 burned 100% No. 2 oil; Sites 3 and 4 burned No. 6 oil (both units burned fuel having the same composition); Site 5 burned a combination of 80% No. 6 oil (by heat input rate) and 20% refinery gas. The "zero level" or base NO_x emission factor for gaseous fuel (containing no fuel-bound nitrogen) was computed by taking the average "as found" NO_x emission factor for all of the sites firing gas fuel only. This value was 58 ng/J. The increase, Δ, in emission factor for No. 2 oil was 34 ng/J (as found). For No. 6/gas fuel the increase over the gas fuel emission factor was 136 ng/J (as found). For No. 6 oil, Δ was 187 ng/J (as found).

By comparing these points to the curve fit of previous laboratory data (Figure 1-2), one observes that in all cases the emissions from low-NO_x burners fall below that curve. It is interesting to note that operation at the optimum low-NO_x mode (represented by squares in Figure 1-2) did not significantly alter the fuel-bound nitrogen conversion to NO_x . Also, with the exception of Site 2 in the as found condition all of the points plotted in Figure 1-2 fall within the boundary curves for the lab data. The effect of fuel nitrogen on NO_x emissions is thus responsible for the large differences in emissions between gas and oil-fired heaters shown in Figures 1-1a and 1-1b.

A summary of NO emissions from the heater configurations studied in this program over the tested range of operating variables is given in Table 1-3. The values reported in parentheses are ppm corrected to 3 percent O_2, dry. (NO_2 emissions were not included in this table due to lack of data at some sites. The data available from Sites 6-10, however, show that the average NO_2 emissions average only 3.6 percent of the total NO_x emissions.)

1.1.2 Past Results - Comparison to Present

In Reference 2 past NO_x emissions data on refinery process heaters firing oil and gas was summarized. These data are presented in Table 1-4. Unfortunately, the paucity of baseline data from oil-fired process heaters with standard burners renders comparisons with the present low-NO_x burner data difficult. Mechanically drafted heaters with low-NO_x burners firing gas,

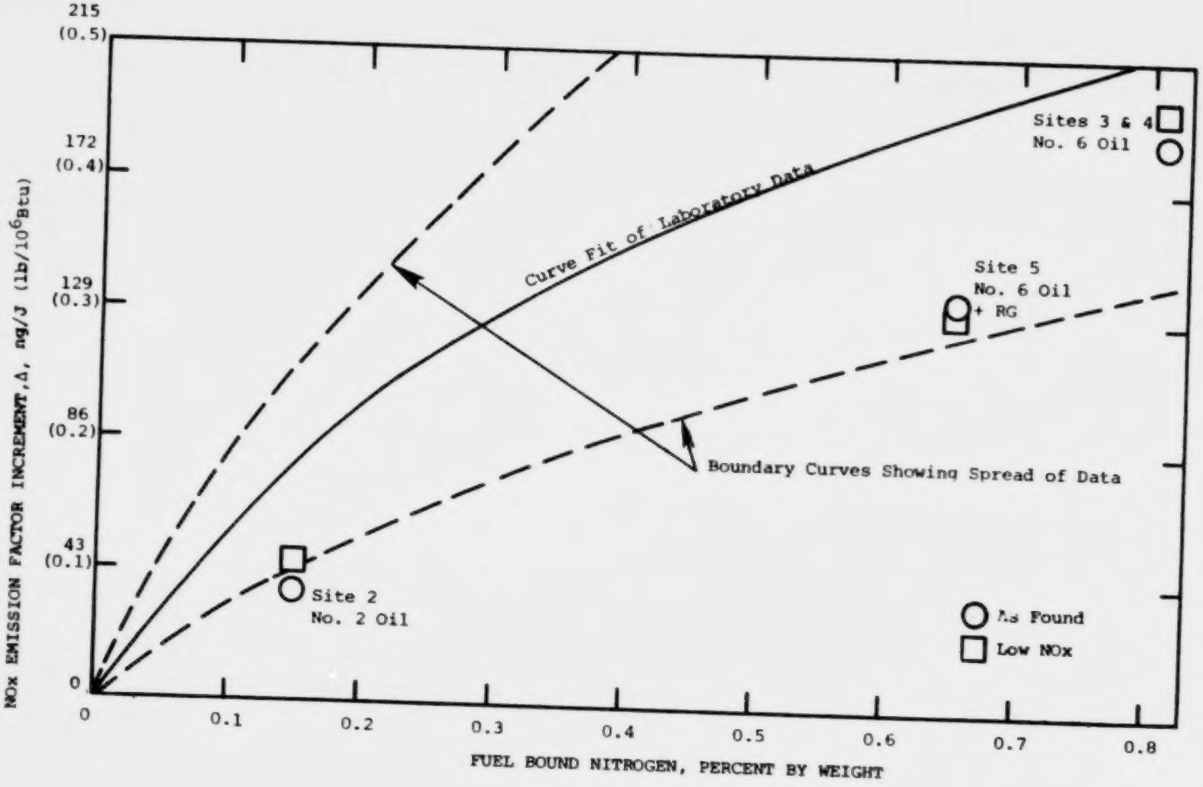

Figure 1-2. Fuel-bound nitrogen effect on NO_x emission factor.

TABLE 1-3. NO EMISSIONS FROM PROCESS HEATERS WITH LOW-NO$_x$ BURNERS

Unit Type	Fuel Type			
	Gas (Ref. or NG)	Distillate Oil	Residual Oil + Gas	Residual Oil
Natural Draft	-	58-117 $\frac{ng}{J}$ (105-212 ppm)	167-202 $\frac{ng}{J}$[1] (303-366 ppm)	207-284 $\frac{ng}{J}$ (369-506 ppm)
Forced Draft, Ambient Air	26-52 $\frac{ng}{J}$ (51-102 ppm)	-	-	-
Balanced Draft, Air Preheat	25-75 $\frac{ng}{J}$ (50-148 ppm)	-	-	-

---

[1] Ratio of heat input from oil to heat input from gas ~83/17

TABLE 1-4. MEAN NO_x EMISSIONS FROM PROCESS HEATERS WITH STANDARD BURNERS

Unit Type	Fuel Type			
	Gas (Ref. or NG)	Distillate Oil	Residual Oil + Gas	Residual Oil
Natural	60.6 $\frac{ng}{J}$ (25 tests)	-	-	-
Mechanical	111 $\frac{ng}{J}$ (6 tests)	-	89.6 $\frac{ng}{J}$[1] (5 tests)	138 $\frac{ng}{J}$ (3 tests)
Not Reported (Bay Area A.P.C.D.)	70.0 $\frac{ng}{J}$ (64 tests)	-	-	-
Not Reported (AP-42)	95 $\frac{ng}{J}$ (8 tests)	198 $\frac{ng}{J}$ (4 tests) - oil - firing only; type unspecified		

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[1] Ratio of heat input from oil to heat input from gas = 60/40

however, appear to have significantly lower NO_x emissions relative to the standard burners. Examination of Tables 1-3 and 1-4 reveals that low-NO_x burners produced NO_x emissions (neglecting NO_2) which were 32 to 77 percent less than the average emission factor for all standard burners on mechanical draft, gas-fired heaters. The variations in NO_x emissions from low-NO_x burners were due to operating differences among units such as excess air level and air register settings. It is important to note that there is no NO_x data available on any of the units tested in this program for operation with standard burners. Thus, a direct comparison of NO_x emissions with and without low-NO_x burners cannot be made for any particular heater. Because of a lack of availability no naturally drafted gas-firing low-NO_x burners were tested during the present program, hence, a comparison with their standard counterparts cannot be made at this time.

1.2 CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE TESTING

The following conclusions may be drawn from the present study:

1. The effectiveness of low-NO_x burners depends upon operating techniques, especially excess air level and air register settings.

2. By making changes in excess air and air register settings, NO_x emissions were reduced at every site with improved overall heater performance.

3. Commercially available low-NO_x burners may reduce the NO_x emission factor by 32 percent to 77 percent below the average emission factor for standard burners on mechanical, draft, gas-fired heaters depending on operating techniques.

4. Because of the lack of a good data base for oil-fired heaters with standard burners, it is felt that a meaningful comparison of the performance of low-NO_x oil-fired burners versus standard oil-fired burners cannot be made at this time.

5. It is recommended that further testing include mechanical draft, oil-fired heaters with and without air preheat and equipped with low-NO_x burners as well as natural draft gas-fired heaters equipped with low-NO_x burners.

6. The existing data on heaters with standard burners has a number of gaps (see Table 1-4); further testing is required on standard burners firing distillate oil (both natural draft and mechanical draft) and standard burners firing residual oil (natural draft) in order to make a more valid comparison to low-NO_x burners.

7. Each test site in the present program was evaluated as to its potential for a 30-day test. Considerations included the following:

   - Fuel type fired
   - Ability to fire this fuel independently of other fuels
   - Availability of the heater and the desired fuel for a period of 30-40 days

   Based on these considerations, the following sites are proposed as the most desirable for 30-day tests:

   - Site 1 - gas-fired, forced draft
   - Site 2 - distillate-oil-fired, natural draft
   - Site 4 - residual-oil-fired, natural draft

Although Sites 6 through 10 are all gas-fired, mechanical draft heaters, they are not deemed desirable sites for a 30-day test because of a concern that the heaters are still undergoing start-up problems, i.e., availability problems. Site 5 fires a combination of gas and oil and thus does not satisfy the fuel specificity requirement. Sites 3 and 4 are both residual-oil-fired, natural draft heaters, but Site 4 is a vertical cylindrical heater similar to the other recommended sites. Because of this similarity in design, it is felt that Site 4 is the better choice of the two sites. The influence of heater design on NO_x emission among the three candidate sites will thus be minimal. Since none of the residual oil tests provided low NO_x levels it may be desirable to select another site.

SECTION 2.0

GASEOUS AND PARTICULATE EMISSIONS TEST METHODS AND INSTRUMENTATION

All emission measurement instrumentation was carried in an 8 x 42 ft mobile laboratory trailer. This trailer was used at all test sites. A plan view of the trailer is shown in Figure 2-1. The gaseous species measurements were made with analyzers located in the trailer.

The emission measurement instrumentation used was the following:

TABLE 2-1. EMISSION MEASUREMENT INSTRUMENTATION

Species	Manufacturer	Measurement Method	Model No
Hydrocarbon	Beckman Instruments	Flame Ionization	402
Carbon Monoxide	Beckman Instruments	IR Spectrometer	865
Oxygen	Teledyne	Polarographic	326A
Carbon Dioxide	Beckman Instruments	IR Spectrometer	864
Nitrogen Oxides	Thermo Electron Co.	Chemiluminescent	10A
Particulates	Joy Manufacturing Co.	EPA Method 5 Train	EPA
Sulfur Dioxide	DuPont Instruments	UV Spectrometer	400

2.1 GAS SAMPLING AND CONDITIONING SYSTEM

A flow schematic of the flue gas sampling and analyzing system is shown in Figure 2-2. The sampling system uses three positive-displacement diaphragm pumps to continuously draw flue gas from the stack into the laboratory. The sample pumps pull from six unheated sample lines. Selector valves allow composites of up to six points to be sampled at one time. The probes are connected to the sample pumps with 0.95 cm (3/8") or 0.64 cm (1/4") nylon line. The positive displacement diaphragm sample pumps provide unheated sample gas to the refrigerated condenser (to reduce the dew point to 35°F), a rotameter with flow control valve, and to the O_2, NO, CO, and CO_2

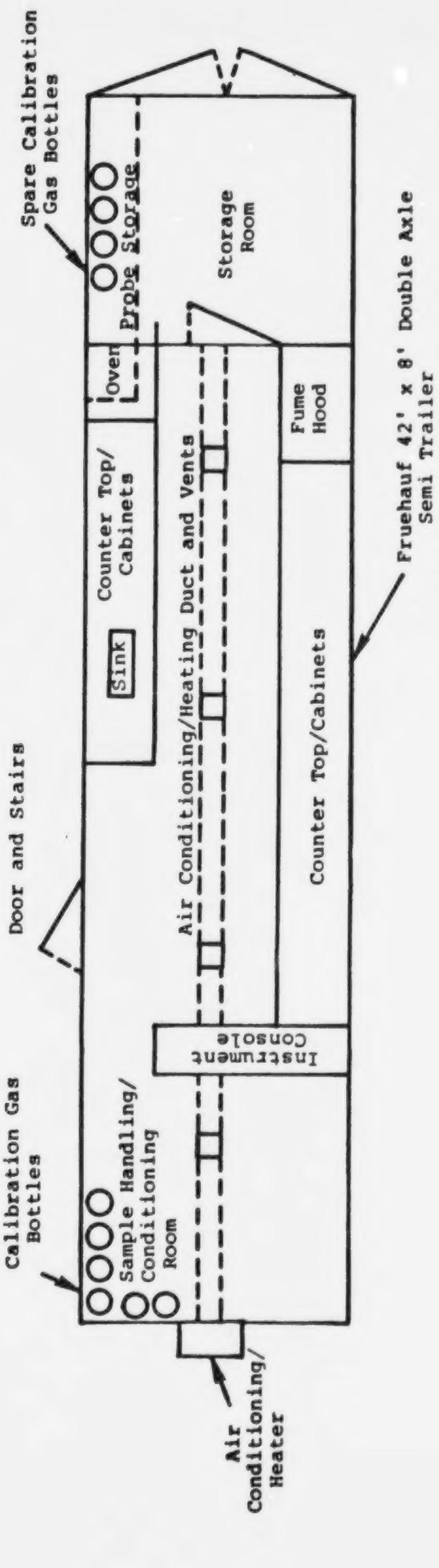
Spare Calibration Gas Bottles
Probe Storage
Storage Room
Oven
Fume Hood
Fruehauf 42' x 8' Double Axle Semi Trailer
Counter Top/ Cabinets
Sink
Air Conditioning/Heating Duct and Vents
Counter Top/Cabinets
Door and Stairs
Instrument Console
Calibration Gas Bottles
Sample Handling/ Conditioning Room
Air Conditioning/ Heater

Figure 2-1. Instrumentation trailer floor plan.

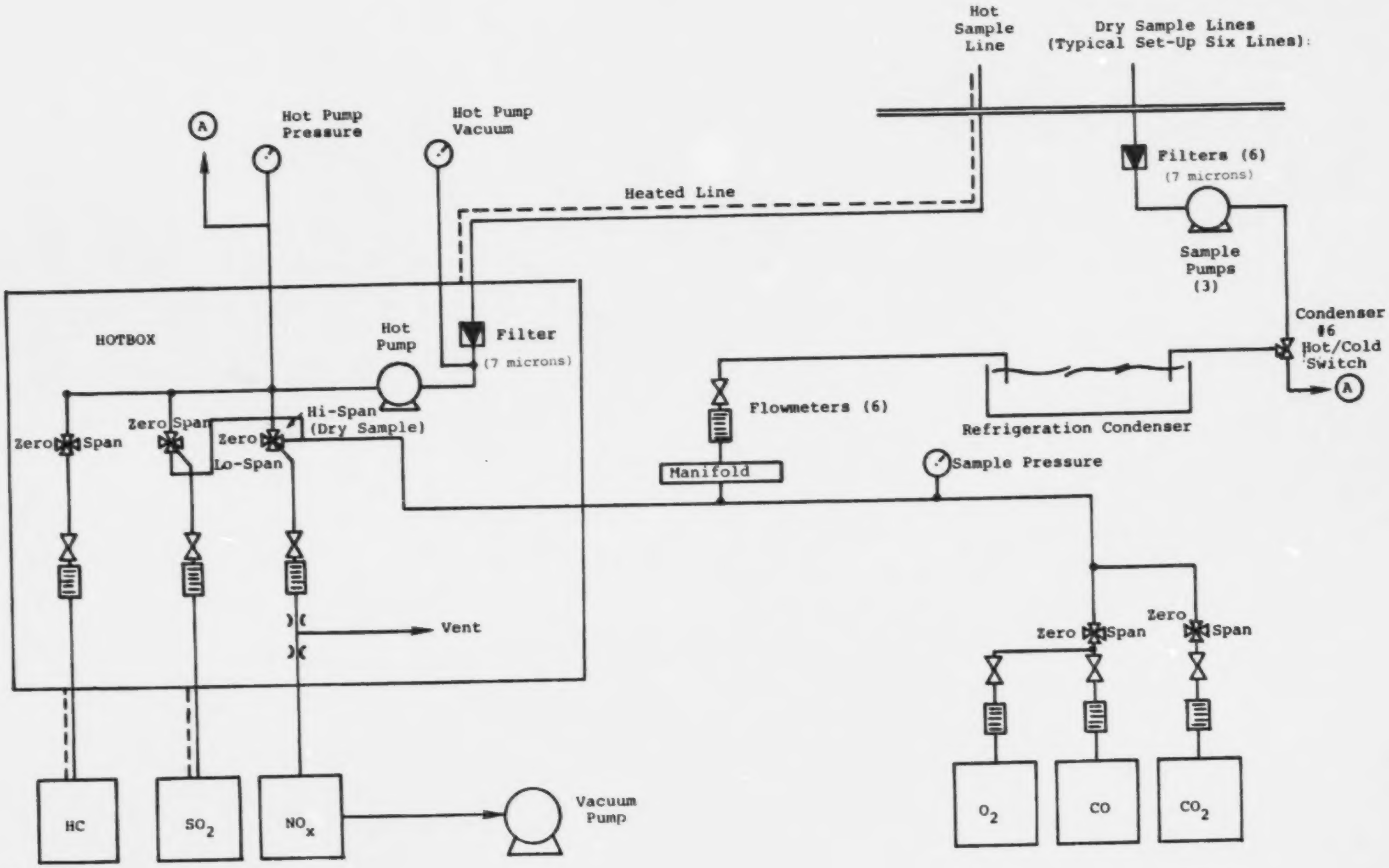
Hot Sample Line
Dry Sample Lines (Typical Set-Up Six Lines):
A
Hot Pump Pressure
Hot Pump Vacuum
Heated Line
Filters (6) (7 microns)
Sample Pumps (3)
Condenser #6 Hot/Cold Switch
A
HOTBOX
Hot Pump
Filter (7 microns)
Hi-Span (Dry Sample)
Zero
Span
Zero
Span
Zero
Lo-Span
Flowmeters (6)
Refrigeration Condenser
Manifold
Sample Pressure
Vent
Zero
Span
Zero
Span
HC
SO2
NOx
Vacuum Pump
O2
CO
CO2

Figure 2-2. Flue gas sampling and analyzing system.

instrumentation. Flow to the individual analyzers is measured and controlled with rotameters and flow control valves. Excess sample is vented to the atmosphere.

To obtain a representative sample for the analysis of NO_2, SO_2 and hydrocarbons, the sample must be kept above its dew point, since heavy hydrocarbons may be condensible, and SO_2 and NO_2 are quite soluble in water. For this reason, a separate electrically-heated sample line is used to bring the sample into the mobile laboratory for analysis. The sample line is 0.95 cm (3/8-inch) Teflon line, electrically traced and thermally insulated to maintain a sample temperature of up to 478 K (400°F). A heated diaphragm pump provides hot sample gas to the hydrocarbon, SO_2 and NO_x analyzers.

2.2 INSTRUMENTAL CONTINUOUS MEASUREMENTS

The laboratory trailer is equipped with analytical instruments to continuously measure concentrations of NO, NO_2, CO, CO_2, O_2, SO_2, and hydrocarbons. All of the continuous monitoring instruments and sample handling system are mounted in the self-contained mobile laboratory. The entire system requires only connection to on-site water, power, and sampling lines to become fully operational. The instruments themselves are shock mounted on a metal console panel. The sample flow control measurement, and selection, together with instrument calibration are all performed from the console face. Three-pen recorders provide a continuous permanent record of the data taken. The sample gas is delivered to the analyzers at the proper condition and flow rate through the sampling and conditioning system described in the previous section. The sections below describe the analytical instrumentation.

2.2.1 Nitric Oxide (NO) and Total Nitrogen Oxides (NO_x)

Both the total nitrogen oxides (NO_x) and nitric oxide (NO) concentrations are measured from a sample gas obtained using a heated sample line at 394 K (250°F). In addition, the nitric oxide concentrations are measured sequentially from samples obtained using the unheated sample line that is connected to the same analyzer in the laboratory trailer. In the latter case, water is first removed from the sample gas by a refrigeration unit. The analytical instrument that is used for all of these measurements is the Thermo Electron Model 10A chemiluminescent gas analyzer.

For NO analyses, the sample gas is passed directly into the reaction chamber where a surplus of ozone is maintained. The reaction between the NO and the ozone produces light energy proportional to the NO concentration which is detected with a photomultiplier and converted to an electrical signal. Air for the ozonator is drawn from ambient through an air dryer and a 10-micrometer filter element.

The chemiluminescent reaction with ozone is specific to NO. To detect NO_2, a thermal converter has been designed to dissociate the NO_2 to NO by the bi-molecular reaction: $2\ NO_2 \quad 2\ NO + O_2$. A model 700 thermal converter is used in conjunction with the chemiluminescent gas analyzer as shown in Figure 2-3. The converter is a coil of resistance-heated stainless steel tubing whose purpose is to drive the NO_2/NO ratio to its chemical equilibrium value at the converter temperature and pressure. The unit is designed to operate at a temperature of 923 K (1200 °F) and pressure of .3 kPa (10 torr). For these conditions and typical stack gas O_2 concentrations, the equilibrium NO_2 concentration is 0.2 percent of the total NO_x concentration. Therefore, when a gas sample containing any NO_2 is passed through the converter, essentially all the NO_2 would be converted to NO. The resulting total NO is then measured using the chemiluminescent analyzer and the difference between the actual NO and the "total NO" would be the sample NO_2 concentration. The "total NO" is interpreted as NO_x.

NO_2 may react upon contact with H_2O (liquid phase) to form HNO_3 (nitric acid). Under field test conditions, the exhaust gas may contain significant H_2O (depending upon the process and the ambient meteorological conditions), and it is necessary to convert the NO_2 to NO before the H_2O is allowed to condense in the sampling system. By using the heated sample line and the Thermo Electron Model 700 heated NO_x module, NO_2 concentrations will effectively be measured. In reference to Figure 2-3, the sample is maintained above the H_2O dew point up to and through the 127 μm (0.005 in.) capillary in

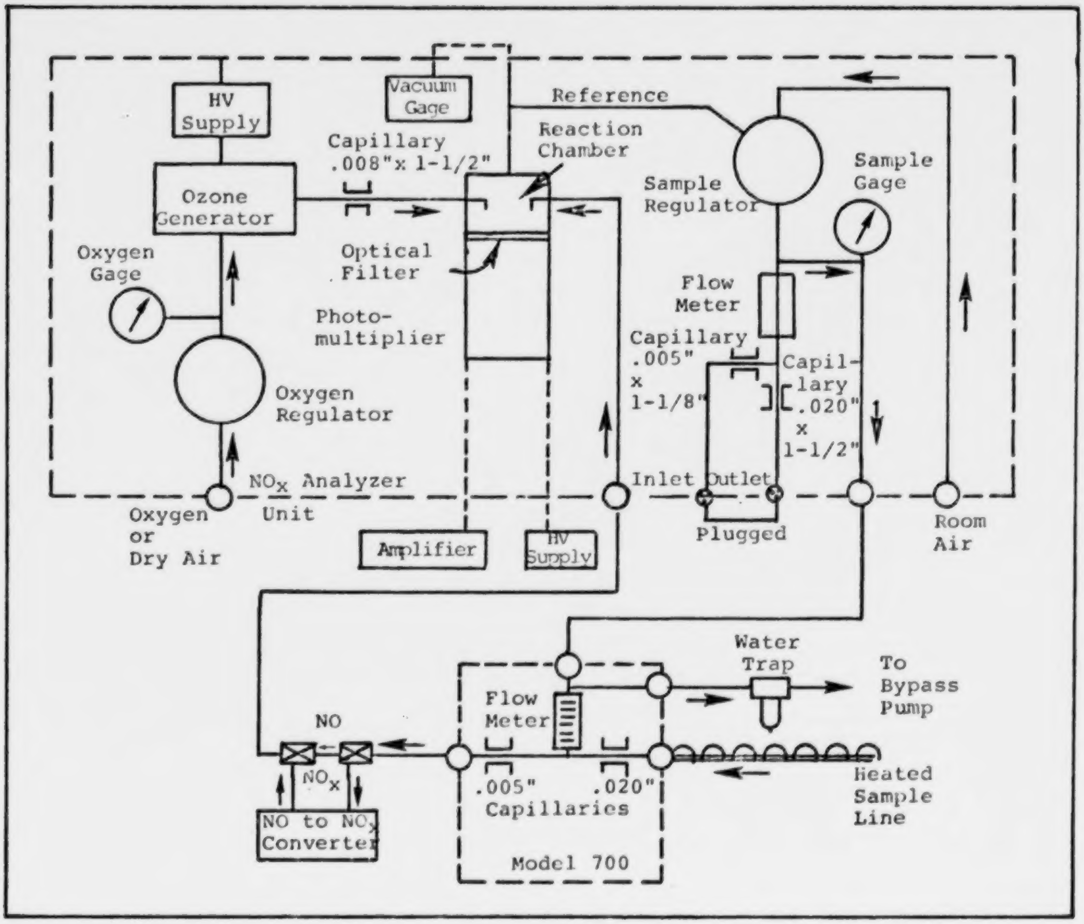
HV Supply
Vacuum Gage
Reference
Capillary .008" x 1-1/2"
Reaction Chamber
Sample Gage
Ozone Generator
Sample Regulator
Optical Filter
Oxygen Gage
Flow Meter
Photo-multiplier
Capillary .005" x 1-1/8"
Capil-lary .020" x 1-1/2"
Oxygen Regulator
NO_x Analyzer Unit
Inlet
Outlet
Plugged
Oxygen or Dry Air
Room Air
Amplifier
HV Supply
Water Trap
To Bypass Pump
Flow Meter
NO
NO_x
NO to NO_x Converter
.005"
.020"
Capillaries
Heated Sample Line
Model 700

Figure 2-3. Schematic of NO_x/NO chemiluminescent analysis system.

the heated module. Downstream of this capillary, the flow network is maintained at 1.3 kPa (10 torr), where the partial pressure of the H_2O in the sample is sufficiently low to prevent any condensation at ambient temperature.

When using the heated system, NO, NO_2, and NO_x are measured on a wet basis. When not using the heated system, a condenser is placed upstream of the analyzer and NO is measured on a dry basis.

Specifications

Accuracy: 1% of full scale

Span stability: ± 1% of full scale in 24 hours

Zero stability: ± 1% ppm in 24 hours

Power requirements: 115 ± 10V, 60 Hz, 1000 watts

Response: 90% of full scale in 1 sec (NO_x mode);
0.7 sec (NO mode)

Output: 4-20 ma

Sensitivity: 0.5 ppm

Linearity: ± 1% of full scale

Vacuum detector operation

Range: 2.5, 10, 25, 100, 250, 1000, 2500, 10,000 ppm full scale

2.2.2 Carbon Monoxide and Carbon Dioxide (CO and CO_2)

Carbon monoxide and carbon dioxide concentrations are measured using Beckman Model 864 and 865 short-path-length nondispersive infrared analyzers (see Figure 2-4). These instruments measure the differential in infrared energy absorbed from energy beams passed through a reference cell (containing a gas selected to have minimal absorption of infrared energy in the wavelength absorbed by the gas component of interest) and a sample cell through which the sample gas flows continuously. The differential absorption appears as a reading on a scale of 0% to 100% and is then related to the concentration of the species of interest by calibration curves supplied with the instrument. A

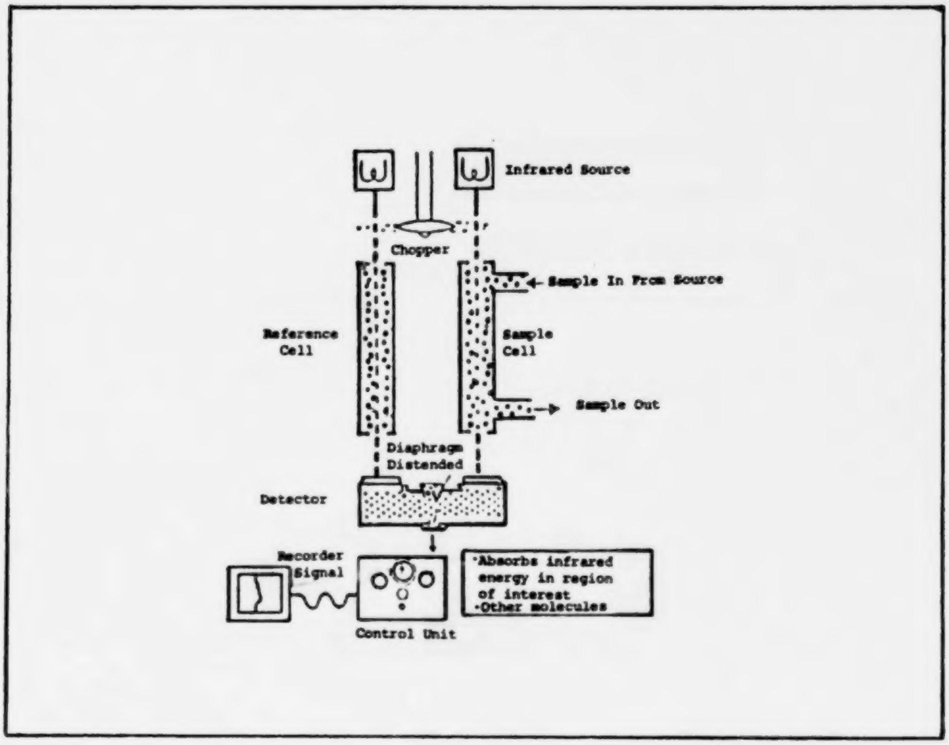
Infrared Source
Chopper
Sample In From Source
Reference Cell
Sample Cell
Sample Out
Diaphragm Distended
Detector
Recorder Signal
Control Unit
·Absorbs infrared energy in region of interest
·Other molecules

Figure 2-4. Schematic of NDIR analyzer.

linearizer is supplied with each analyzer to provide a linear output over the range of interest. The operating ranges for the CO analyzer are 0-100 and 0-2000 ppm, while the ranges for the CO_2 analyzer are 0-5% and 0-20%.

Specifications

Span stability: ± 1% of full scale in 24 hours

Zero stability: ± 1 ppm in 24 hours

Ambient temperature range: 273 to 322 K (32°F to 120°F)

Line voltage: 115 ± 15V rms

Response: 90% of full scale in 0.5 or 2.5 sec

Linearity: Linearizer board installed for one range

Precision: ± 1% of full scale

Output: 4-20 ma

2.2.3 Oxygen (O_2)

A Teledyne Model 326A oxygen analyzer is used to automatically and continuously measure the oxygen content of the flue gas sample. The analyzer utilizes a micro-fuel cell which is specific for oxygen, has an absolute zero, and produces a linear output from zero through 25 percent oxygen. The micro-fuel cell is a sealed electrochemical transducer with no electrolyte to change or electrodes to clean. Oxygen in the flue gas diffuses through a Teflon membrane and is reduced on the surface of the cathode. A corresponding oxidation occurs at the anode internally and an electric current is produced that is proportional to the concentration of oxygen. This current is measured and conditioned by the instrument's electronic circuitry to give an output in percent O_2 by volume for operating ranges of 0% to 5%, 0% to 10%, and 0% to 25%.

Specifications

Precision: ± 1% of full scale

Response: 90% in less than 40 sec

Sensitivity: 1% of low range

Linerity: ± 1% of full scale

Ambient temperature range: 273 K to 325 K (32°F to 125°F)

Fuel cell life expectancy: 40,000% +-hrs

Power requirement: 115 VAC, 50-60 Hz, 100 watts

Output: 4-20 ma

2.2.4 Total Hydrocarbons (HC)

Hydrocarbon emissions are measured using a Beckman Model 402 high-temperature hydrocarbon analyzer. The analyzer utilizes the flame ionization method of detection which is a proven technique for a wide range of concentrations (0.1 to 120,000 ppm). A flow schematic of the analyzer is presented in Figure 2-5. The sensor is a burner where a regulated flow of sample gas passes through a flame sustained by regulated flows of air and a premixed hydrogen/nitrogen fuel gas. Within the flame the hydrocarbon components of the sample stream undergo a complex ionization that produces electrons and positive ions. Polarized electrodes collect these ions, causing current to flow through electronic measuring circuitry. Current flow is proportional to the rate at which carbon atoms enter the burner.

The analysis occurs in a temperature-controlled oven. The sample is extracted from the stack with a stainless steel probe which has been thermally treated and purged to eliminate any hydrocarbons existing in the probe itself. An insulated heat-traced teflon line is used to transfer the sample to the analyzer. The entire heated network is maintained at a temperature to prevent condensation of heavier hydrocarbons.

The flame ionization detector is calibrated with methane, and the total hydrocarbon concentration is reported as the methane equivalent. FID's do not respond equally to all hydrocarbons but generally provide a measure of

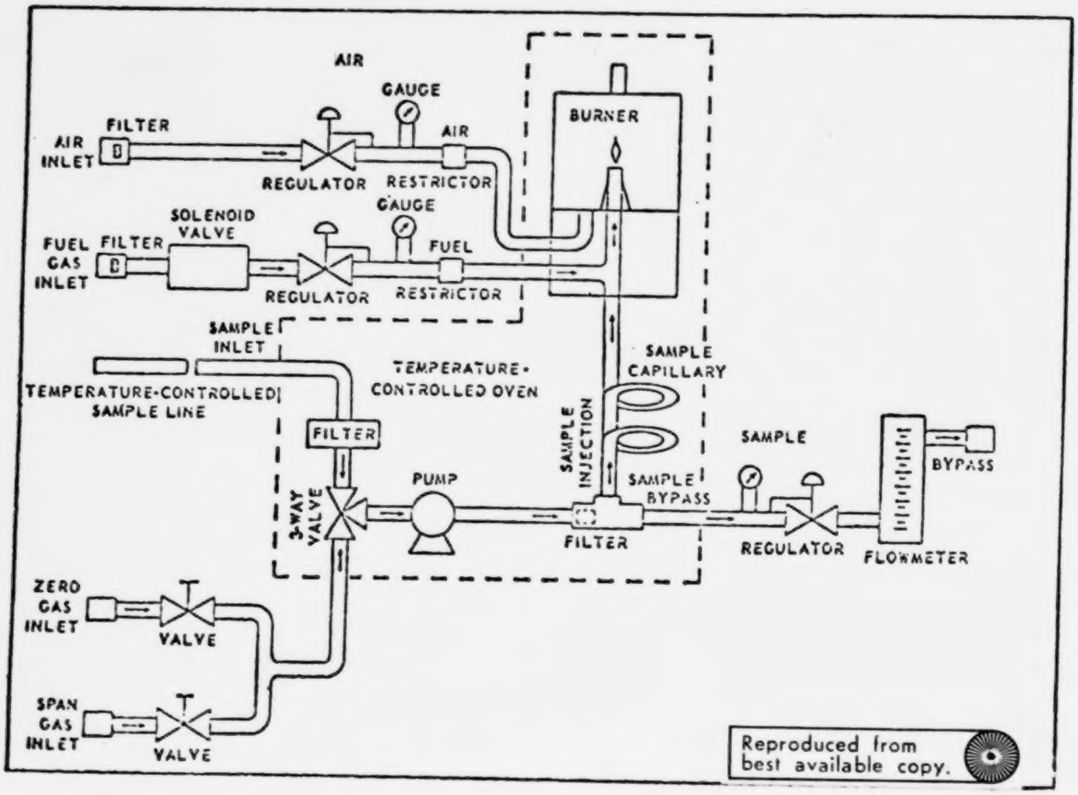
AIR
GAUGE
FILTER
AIR INLET
REGULATOR
AIR
RESTRICTOR
BURNER
SOLENOID VALVE
GAUGE
FUEL GAS INLET
FILTER
REGULATOR
FUEL
RESTRICTOR
SAMPLE INLET
TEMPERATURE-CONTROLLED OVEN
TEMPERATURE-CONTROLLED SAMPLE LINE
SAMPLE CAPILLARY
SAMPLE INJECTION
FILTER
3-WAY VALVE
PUMP
SAMPLE BYPASS
FILTER
SAMPLE
REGULATOR
BYPASS
FLOWMETER
ZERO GAS INLET
VALVE
SPAN GAS INLET
VALVE

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Figure 2-5. Flow schematic of hydrocarbon analyzer (FID).

the carbon-hydrogen bonds present in the molecule. The FID does not detect pure carbon or hydrogen.

Specifications

Full-scale sensitivity: adjustable from 5 ppm CH_4 to 10% CH_4

Ranges: Range multiplier switch has 8 positions: X1, X5, X10, X50, X100, X500, X1000, and X5000. In addition, span control provides continuously variable adjustment within a dynamic range of 10:1

Response time: 90% full scale in 0.5 sec

Precision: ± 1% of full scale

Electronic stability: ± 1% of full scale per 24 hours with ambient temperature change of less than 10°F

Reproducibility: ± 1% of full scale for successive identical samples

Analysis temperature: ambient

Ambient temperature: 273 K to 317 K (32°F to 100°F)

Output: 4-20 ma

Air requirements: 250 to 400 cc/min of clean, hydrocarbon-free air, supplied at 2.07×10^5 to 1.38×10^6 n/m^2 (30 to 200 psig)

Fuel gas requirements: 75 to 80 cc/min of fuel consisting of 100 percent hydrogen supplied at 2.07×10^5 to 1.38×10^6 n/m^2 (30 to 200 psig)

Electric power requirements: 120 V, 60 Hz

Automatic flame indication and fuel shut-off valve

2.2.5 Sulfur Dioxide (SO_2)

A Dupont Model 400 photometric analyzer is used for measuring SO_2. This analyzer measures the difference in absorption of two distinct wavelengths (ultraviolet) by the sample. The radiation from a selected light source passes through the sample and then into the photometer unit where the radiation is split by a semi-transparent mirror into two beams. One beam is directed to a phototube through a filter which removes all wavelengths except the "measuring" wavelength, which is strongly absorbed by the constituent in the sample. A second beam falls on a reference phototube, after passing through an optical filter which transmits only the "reference" wavelength. The latter is absorbed only weakly, or not at all, by the constituent in the sample cell. The phototubes translate these intensities to proportional electric currents in the amplifier. In the amplifier, full correction is made for the logarithmic relationships between the ratio of the intensities and concentration or thickness (in accordance with Beer's Law). The output is therefore linearly proportional, at all times, to the concentration and thickness of the sample. The instrument has a lower detection limit of 2 ppm and full scale ranges of 0-200 and 0-2000 ppm.

Specifications

Noise: Less than 1/4%

Drift: Less than 1% full scale in 24 hours

Accuracy: (± 1% of analyzer reading) + (± 1/4% of full scale range)

Sample cell: 304 stainless steel, quartz windows

Flow rate: 6 CFH

Light source: Either mercury vapor, tungsten, or "Osram"
discharge type lamps

Power rating: 500 watts maximum, 115 V, 60 Hz

Reproducibility: 1/4% of scale

Electronic response: 90% in 1 sec

Sample temperature: 378 K (220°F)

Output: 4-20 ma d.c.

2.3 PARTICULATE MATTER TOTAL MASS CONCENTRATION

Particulate matter is collected by filtration and wet impingement in accordance with US-EPA Method No. 5. Nomograph techniques are utilized to select the proper nozzle size and to set the isokinetic flow rates.

Gas samples for particulate sampling can be taken from the same sample port as those for gas analysis and passed through the Joy Manufacturing Company Portable Effluent Sampler. This system, which meets the EPA design specifications for Test Method 5, Determination of Particulate Emissions from Stationary Sources (Federal Register, Volume 36, No. 27, page 24888, December 24, 1971, and revisions thereof) is used to perform both the initial velocity traverse and the particulate sample collection.

Dry particulates are collected in the heated case that may contain a cyclone to separate particles larger than 5 μm and a 125-mm glass-fiber filter to retain particles as small as 0.3 μm. Condensible particulates are collected in four Greenburg-Smith impingers immersed in a chilled water bath.

The sampling probe is positioned through an exhaust port and attached to the sampling box. The probe consists of a sampling nozzle, heated probe, gaseous probe, thermocouple, and pitot tube. The ball joint from the heated probe connects to the cyclone and glass filter holder assembly. These assemblies are positioned in the heated sampling box which is maintained at 433 K (320°F), i.e. above the predicted SO_3 dew point, in order to eliminate condensation. The sample then passes from the heated section to four Greenburg-Smith impingers immersed in an ice bath. Only the second impinger has the original tip, the other three have had the tip removed to decrease the pressure drop through them. The first and second impingers are filled with 250 and 150 milliliters of distilled/deionized water, respectively. The third impinger is left dry. The fourth impinger is filled with approximately 200 grams of indicating silica gel to remove entrained water. The use of silica gel assures that a dry sample is delivered to the meter box. After sampling, the spent silica gel is discarded and not used for any further analysis.

An umbilical cord connects the last impinger, the pitot tube, and the heating elements to the meter box which is located in a convenient place within 15 m of the sampling ports. The meter box contains a vacuum pump, regulating valves, instantaneous and integrating flow meters, pitot tube manometers, vacuum gauge, and electrical controls.

Particulate matter (solids and condensibles) is collected in three discrete portions by the sampling train: the probe and glassware upstream of the filter; the filter; and the wet impingers. The probe and glassware are brushed and rinsed with acetone; the matter is captured for gravimetric analysis. The probe and glassware are then rinsed with distilled water and the rinsings transferred to a second container for analysis. The filter is desiccated and analyzed gravimetrically. The combined impinger liquid is heated to drive off uncombined water and the residue retained for analysis. The particulate matter analysis is illustrated schematically in Figure 2-6.

US EPA Method 5 considers the particulate matter captured in containers (1) and (3); the filter, probe brushing, and probe acetone rinse. As EPA source standards are based on solid particulates only, care is taken to differentiate between solid and the total (including condensible) particulates. The water wash is performed because KVB's test experience has shown that a significant amount of water-soluble material may sometimes be captured by the probe.

The dry sample volume is determined with a dry test meter at a measured temperature and pressure and then converted to standard conditions. The volume of condensed water in the impingers is measured in milliliters and the corresponding volume of water vapor is then computed at standard conditions. The dry sample volume and water vapor volume are then summed to give the total sample volume. The dry sample volume is used in the data reduction procedures.

A point of interest is the method chosen to calculate particulate emissions in ng/J or $lb/10^6$ Btu from the experimental data. The particulate sampling train, properly operated, yields particulate mass per unit flue gas volume. Having measured g/m^3, it is necessary to establish the flue gas volume per unit heat input if emissions in ng/J are desired. The original Method 5 involved determining a velocity traverse of the stack, the cross-sectional area, the flue flow rate, and fuel heating value. A revised and

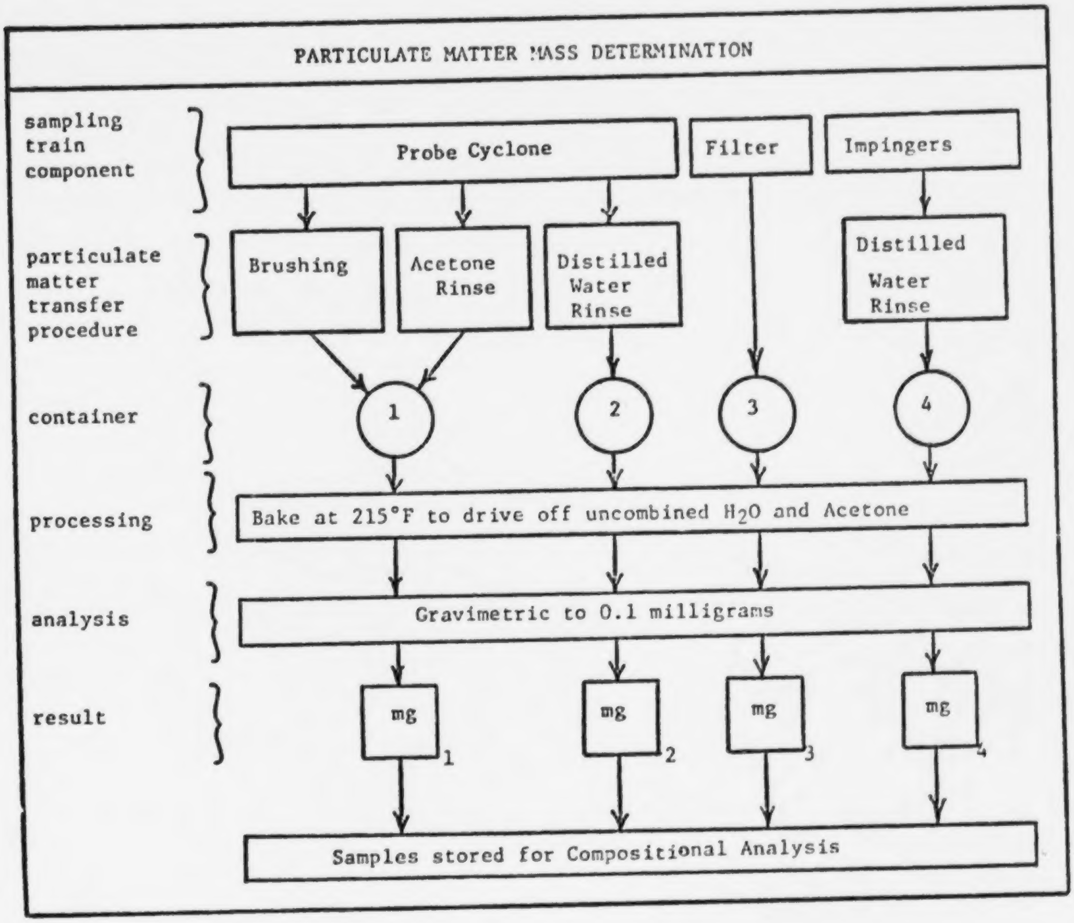
PARTICULATE MATTER MASS DETERMINATION
sampling train component
particulate matter transfer procedure
container
processing
analysis
result
Probe Cyclone
Filter
Impingers
Brushing
Acetone Rinse
Distilled Water Rinse
Distilled Water Rinse
1
2
3
4
Bake at 215°F to drive off uncombined H2O and Acetone
Gravimetric to 0.1 milligrams
mg 1
mg 2
mg 3
mg 4
Samples stored for Compositional Analysis

Figure 2-6. Processing and analyzing particulate matter.

more accurate method has been promulgated by the Environmental Protection Agency that utilizes a fuel analysis (carbon content, hydrogen content, high heating value, etc.) and the measured O_2 in the exhaust to calculate the gas volume generated in liberating 1.055 GJ (a million Btu's). The velocity traverse approach generally results in a 20 to 30 percent higher value and is believed to be less accurate.

SECTION 3.0

SITE-BY-SITE SUMMARY/UNIT DESCRIPTIONS AND TEST RESULTS

This section contains a description of each of the ten process heaters tested as well as a discussion of the test sequence and data obtained for each site. Heaters are grouped according to their fuel type and draft configurations (e.g. gaseous fuel and mechanical draft, residual oil and natural draft).

3.1 GAS-FIRED, MECHANICAL-DRAFT PROCESS HEATERS

3.1.1 Site 1

The first process heater tested under this task was a vertical cylindrical forced draft heater rated at 92.7 m^3/h (14,000 bbl/day) throughput. The unit was fired with a combination of natural gas and refinery off-gas. Three burners, firing vertically upward, were supplied with combustion air by a single forced draft fan. Although the burners were originally designed for a natural draft application, a city ordinance limiting stack height necessitated the conversion to forced draft.

The heater was initially tested in the "as found" condition before any adjustments were made. The heater was operating at 10.5 percent excess O_2 at a process rate of 53.0 m^3/h (8,000 bbl/day) throughput with NO emissions of 87 ppm, dry at 3 percent O_2. The O_2 was then reduced in stages at a constant load until the smoke limit was reached. The effect of excess air on NO emissions at 53.0 m^3/h is shown in Figure 3-1. All emission measurements were made at the stack. Following the excess air survey test, a baseline condition of 4 percent O_2 was set and burner air register adjustments were made. The same test procedure was followed at the higher load condition of 72.9 m^3/h (11,000 bbl/day). These data are also presented in Figure 3-1 where NO as a

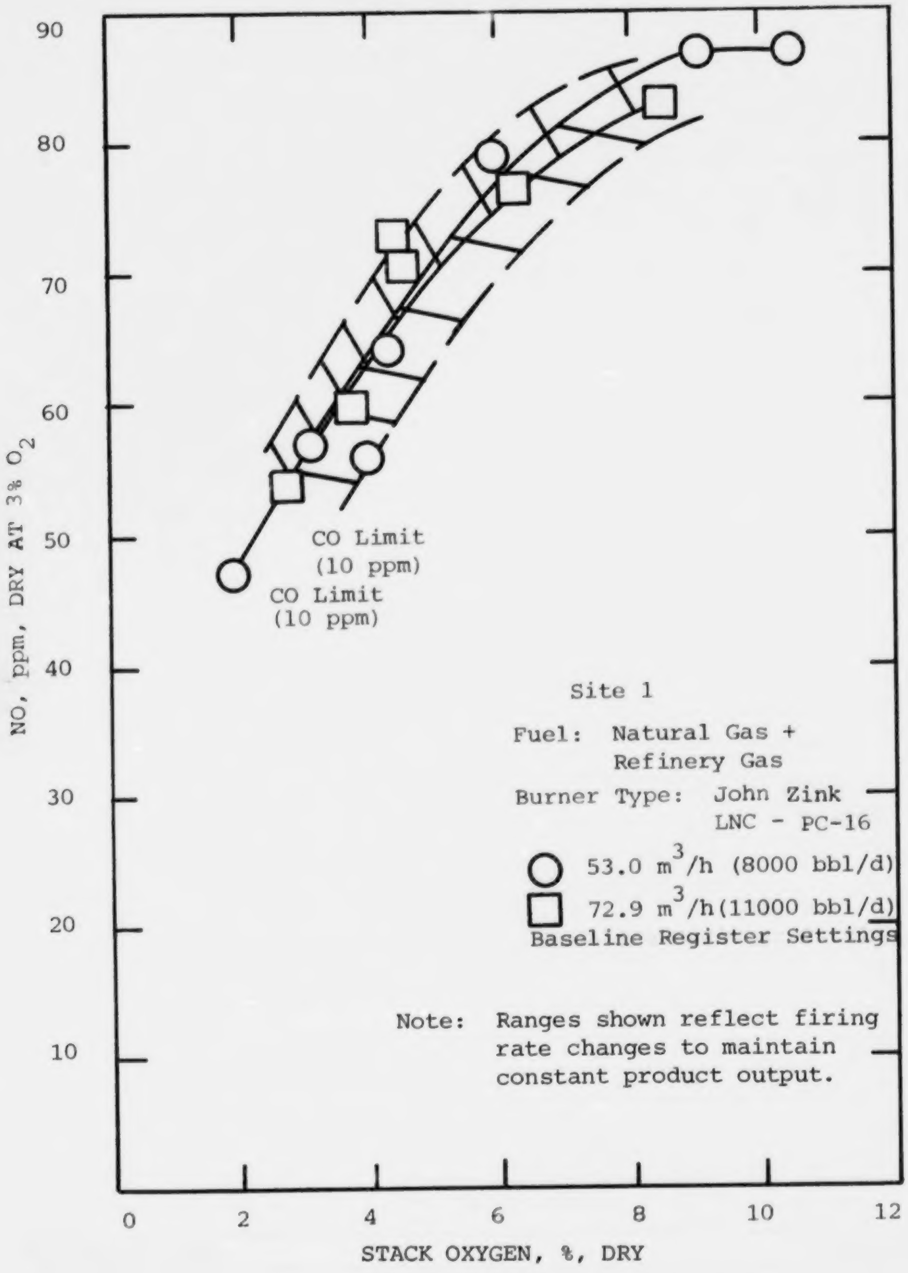

Figure 3-1. NO emission as a function of stack oxygen for a process heater equipped with low-NO_x burners.

function of stack excess oxygen is plotted for both load conditions. All the pertinent operating data are summarized in Table 3-1. A sample of the refinery gas was taken and submitted for analysis.

The results of the fuel analyses for the refinery gas and the natural gas fuels used at Site 1 are given in Table 3-2.

3.1.2 Sites 6-10

A reformer heater comprised of four separate rectangular "cells" or sections provided Sites 6 through 9 and Site 10 was a debutanizer bottoms reboiler. The reformer had a maximum capacity of 132 m^3/h (20,000 bbl/d) of reformate. The debutanizer reboiler had a maximum capacity of 197 m^3/h (29,672 bbl/d) of product. Both units came on line for the first time in September, 1980.

The cells of the reformer, labeled A through D, were balanced draft units each having eight wall burners firing refinery gas. A single forced draft fan supplied the combustion air for all the cells and the air was preheated to a temperature of approximately 544K (520°F). An induced draft fan was used to draw the flue gas from all of the cells through the air preheater and out of the stack.

Each cell performed a different duty and was separated by a division wall from adjacent cells so that for all practical purposes the reformer actually consisted of four separate units. Each unit supplied a different reforming reactor with the proper initial product state for that reactor. Thus, Cell A corresponds to the Site 6 designation, Cell B to Site 7, Cell C to Site 8, and Cell D to Site 9.

A schematic of the reformer and the reboiler is shown in Figure 3-2. The figure shows how combustion air was supplied to each of the wall burners in the reformer. For each cell there were two main combustion air dampers, one for the North side and one for the South side. In addition, there was a separate air damper for each of the burners. There were four wall burners on the North side and four on the South side of the furnace. The burners were operated at a relatively low pressure drop. Fuel pressure at the burner was typically 13.8 kPa (2.0 psig) which was significantly lower than burners

TABLE 3-1. SITE 1. SUMMARY OF GASEOUS EMISSION AND EFFICIENCY FOR A FORCED DRAFT PROCESS HEATER EQUIPPED WITH LOW-NO_x BURNERS

Test No.	Date 1980	Process Rate		Heat Input		Fuel Split as % of Heat Input		O_2 %, Dry	CO_2 %, Dry	NO		CO ppm*	SO_2 ppm*	Stack Temp.		Heater Eff. %	Air Registers % Open			Comments
		m^3/h	bbl/d	MW	10^6 Btu/hr	NG	Ref. Gas			ppm*	ng/J			K	°F		Pri.	Sec.	Ter.	
1-1	10/1	53.00	8,000	4.16	14.2	64.4	35.6	10.5	5.5	87	44	0	38	497	435	76.5	60	100	100	As found, medium load
1-2	10/1	53.00	8,000	3.78	12.9	70.9	29.1	9.0	6.2	87	44	0	33	479	402	78.0	60	100	100	Excess O_2 variation
1-3	10/1	53.00	8,000	3.68	12.6	72.9	27.1	3.1	10.6	57	29	20	23	450	350	83.0	60	100	100	Excess O_2 variation
1-4	10/1	53.00	8,000	3.58	12.2	74.9	25.1	1.9	11.5	47	24	57	90	434	321	83.0	60	100	100	Excess O_2 variation, smoke limit
1-5	10/1	53.00	8,000	3.48	11.9	77.0	23.0	5.9	9.3	79	40	24	136	439	330	84.5	60	100	100	Excess O_2 variation
1-6	10/2	53.00	8,000	3.95	13.5	49.3	50.7	4.0	10.0	56	29	11	146	461	370	82.8	60	100	100	Baseline, medium load
1-7	10/2	53.00	8,000	4.01	13.7	48.6	51.4	4.2	10.0	60	31	11	160	461	370	82.8	0	100	100	Air register adjustment, crude tank switch
1-8	10/2	53.00	8,000	4.01	13.7	48.6	51.4	4.2	10.0	64	33	11	148	458	365	82.8	100	50	100	Air register adjustment
1-9	10/2	53.00	8,000	3.96	13.5	49.2	50.8	3.7	10.3	53	27	21	144	456	361	83.0	100	10	100	Air register adjustment
1-10	10/2	53.00	8,000	3.91	13.3	49.8	50.2	4.2	10.0	55	28	21	123	456	361	83.0	50	10	100	Air register adjustment, poor mixing
1-11	10/2	53.00	8,000	3.80	13.0	48.3	51.7	4.0	9.6	64	33	11	134	458	365	82.8	60	100	100	Baseline
1-12	10/2	53.00	8,000	3.70	12.6	49.6	50.4	4.3	9.6	72	37	11	124	458	365	82.8	60	100	0	Air register adjustment
1-13	10/3	72.87	11,000	4.63	15.8	37.5	62.5	6.2	8.4	77	39	0	219	494	430	79.9	60	100	100	As found, higher load
1-14	10/3	73.13	11,040	4.63	15.8	37.5	62.5	3.7	10.2	60	31	0	191	484	412	81.8	60	100	100	Baseline, higher load
1-15	10/3	73.13	11,040	4.53	15.5	38.3	61.7	2.7	10.6	54	28	10	182	476	398	82.5	60	100	100	Excess O_2 variation, smoke limits
1-16	10/3	73.13	11,040	4.48	15.3	38.7	61.3	8.5	6.9	83	42	0	159	505	450	78.1	60	100	100	Excess O_2 variation
1-17	10/3	72.87	11,000	4.81	16.4	52.2	47.8	4.4	9.6	73	37	5	168	469	385	82.2	60	100	100	Baseline variation, crude tank switch
1-18	10/3	73.13	11,040	4.85	16.5	50.4	49.6	4.2	9.6	70	36	5	172	469	385	82.2	0	100	100	Air register adjustment
1-19	10/3	72.87	11,000	4.85	16.5	50.4	49.6	4.4	9.8	65	33	0	174	472	390	81.9	100	0	100	Air register adjustment
1-20	10/3	72.87	11,000	4.85	16.5	50.4	49.6	4.4	9.8	68	35	0	162	469	385	81.9	50	50	100	Air register adjustment
1-21	10/3	72.87	11,000	4.85	16.5	50.4	49.6	4.5	9.3	63	32	11	175	469	385	81.9	0	50	100	Air register adjustment
1-22	10/3	73.13	11,040	4.85	16.5	50.4	49.6	4.5	9.3	71	36	6	169	469	385	81.9	60	100	100	Baseline
1-23	10/3	73.13	11,040	4.54	15.5	47.1	52.9	4.3	9.6	77	39	0	173	469	385	81.9	60	100	0	Air register adjustment
1-24	10/3	73.13	11,040	4.59	15.7	46.6	53.4	3.0	10.3	48	24	20	180	461	370	83.0	100	0	100	Optimum low-NO_x register settings + low O_2

*ppm @ 3% O_2, dry basis

TABLE 3-2. FUEL ANALYSES AT SITE 1

Fuel Sample No. 1
Test 1-6
Sample Taken 10/2/80

Gaseous Species	Volume %
O_2	0.025
N_2	0.340
CH_4	8.93
CO_2	4.25
C_2H_6	6.09
C_3H_8	20.47
C_4H_{10}	31.63
C_5H_{12}	16.24
$\geq C_6$	11.87
CO	1000 ppm

HHV (Higher Heating Value) 107,500 kJ/m^3 (2,885 Btu/ft^3).

$K^1_{NO_x}$ = 1.933

Natural Gas
Typical for all tests.

Gaseous Species	Volume %
Methane	88.09
Ethane	6.84
Propane	1.51
Isobutane	0.29
Nitrogen	1.47
Carbon Dioxide	1.73

HHV (Higher Heating Value) 38,861 kJ/m^3 (1,043 Btu/ft^3).

K_{NO_x} = 1.939

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[1] ng/J = (ppm of NO_x at 3% O_2)/K_{NO_x}

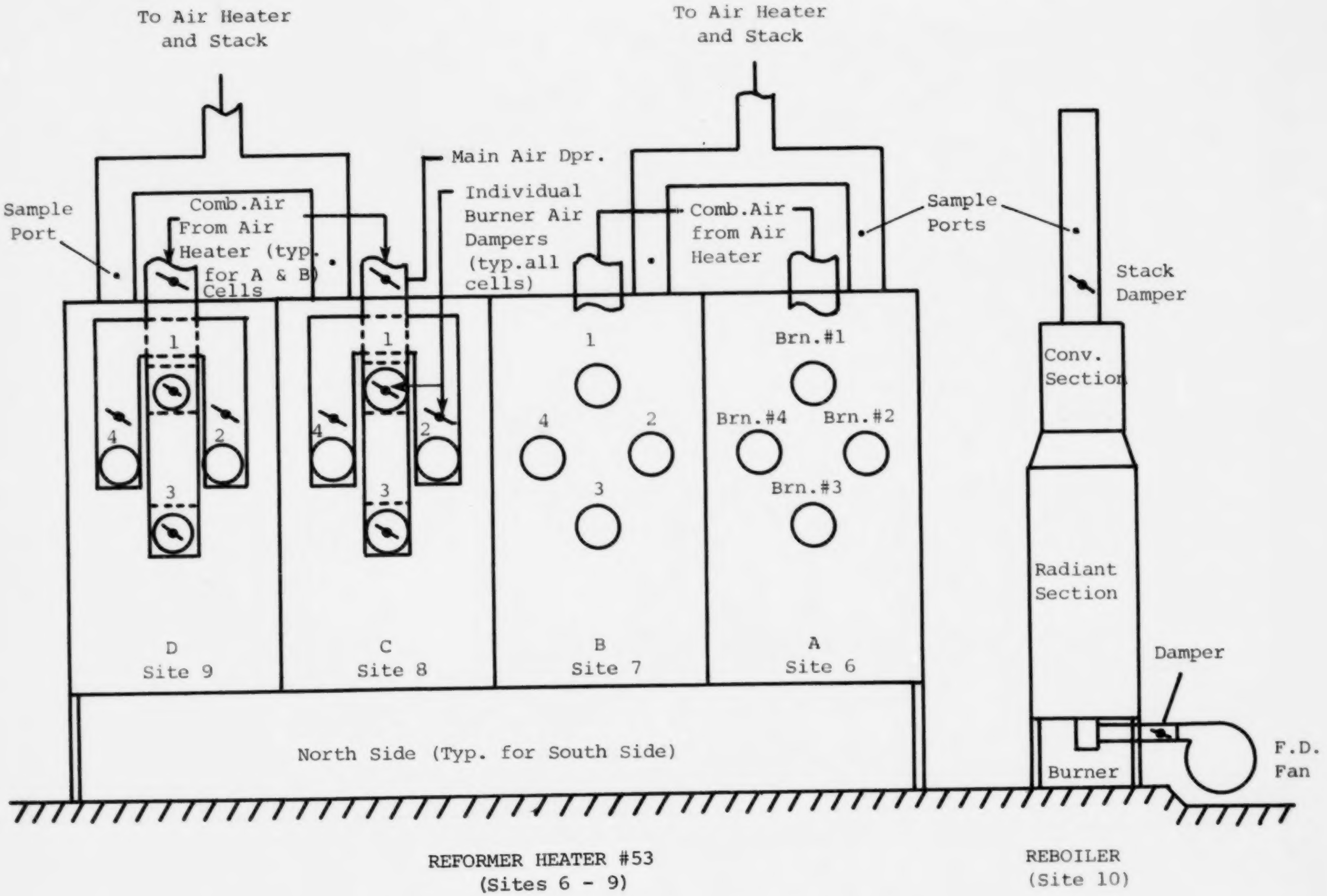
To Air Heater and Stack
To Air Heater and Stack
Main Air Dpr.
Individual Burner Air Dampers (typ.all cells)
Sample Port
Comb.Air From Air Heater (typ. for A & B Cells
Comb.Air from Air Heater
Sample Ports
Stack Damper
Conv. Section
Radiant Section
Damper
Burner
F.D. Fan
1
2
3
4
1
2
3
4
1
2
3
4
Brn.#1
Brn.#2
Brn.#3
Brn.#4
D Site 9
C Site 8
B Site 7
A Site 6
North Side (Typ. for South Side)
REFORMER HEATER #53 (Sites 6 - 9)
REBOILER (Site 10)

Figure 3-2. Schematic of Reformer Heater (Cells A, B, C, D) and Reboiler - Sites 6 through 10.

tested previously. At previous test sites gaseous fuel burner pressures were on the order of 68.9 kPa (10.0 psig). Some swirl was imparted to the fuel in order to improve mixing and maintain flame stability at these low burner pressures.

Gaseous emissions were measured at the outlet of the radiant section of each cell upstream of the convection section (not shown in Figure 3-2). This was done because the convection section was common to two heater cells, i.e. the flue gas out of one convection section actually came from two heaters.

Oxygen was varied on each of the cells of the platform heater. In addition, the distribution of the combustion air was varied on each cell by increasing the air flow to one side of the furnace while at the same time decreasing the air flow to the other side. The latter modification provided a means for off-stoichiometric combustion and was tested both at baseline and at low overall oxygen conditions. Individual burner damper settings were not changed because they had previously been optimized by the burner manufacturer. Because of the lack of operating experience with these burners it was agreed that changes in air distribution be made by the burner manufacturer only.

The debutanizer bottoms reboiler (site 10) had a vertical cylindrical radiant section and a rectangular convection section. A single floor-mounted burner of the same design as those used in the platform heater was supplied with combustion air by a forced draft fan. The furnace draft and excess air controls were a forced draft fan damper as well as a stack damper (see Figure 3-2). Emission measurements were made at the stack above the convection section.

Since the forced draft fan damper was nearly closed in the as found condition with the oxygen level still rather high, adjustments in excess air levels were accomplished by changing the stack damper position. In this manner an excess air survey was carried out on the reboiler. No further modifications were possible on this unit since it contained only one burner and since the introduction of the combustion air had been optimized by the burner manufacturer.

The gaseous emission data obtained at Sites 6-10 are contained in Table 3-3. The analyses of the refinery gas used at these five sites are given in Table 3-4.

The results of the excess air variation tests on heater Sites 6 through 9 (balanced draft heaters with combustion air preheat) are shown in Figure 3-3. Except for one test series at Site 6, all of the data in Figure 3-3 were obtained with the heaters operating at 80 percent of capacity. A strong dependence of NO emissions on excess air is indicated for all of the units as well as a noticeable dependence on heater size. Emissions increase with both excess air and unit size (heat input rate). At Site 6 increasing the process rate from 106 m^3/h (16,000 bbl/d) to 132 m^3/h (20,000 bbl/d) appears to have "flattened" the NO vs O_2 curve such that NO emissions were higher at low O_2 (<4 percent) than they were at the lower load and lower at high O_2 (>4 percent) than they were at the lower load.

The effect of biased combustion air or off-stoichiometric firing on NO emissions was not noticeable except at Site 7 where a slight reduction in NO was observed. At Site 6 some very low NO_x emissions were observed in two biased firing tests (Tests 6/3-1 and 6/3-2); however, these levels were not repeatable and it is believed that they may have been caused by short-term changes in the refinery gas fuel composition and/or unit operating conditions. These points are not plotted in Figure 3-2, however, they are listed in Table 3-3.

The average "as found" NO emissions for the four balanced draft, preheated air units at 80 percent capacity was 128 ppm, dry at 3 percent O_2 with the highest measured concentration being 148 ppm (Site 8) and the lowest being 114 ppm (Site 6). By adjusting excess air and/or biasing the combustion air to achieve optimum firing conditions the NO emissions were reduced to an average level of 67 ppm for the four heater cells. The range of NO emissions in the optimum low-NO_x condition for the four cells was 50-81 ppm.

NO_2 emissions for the four heater cells averaged less than 4 percent of the NO emissions. Only traces of CO were present during all of the tests.

TABLE 3-3. SUMMARY OF GASEOUS EMISSIONS FROM REFINERY PROCESS HEATERS EQUIPPED WITH LOW-NO_x BURNERS, SITES 6-10

Test No.	Date 1980	Process Rate m^3/h	Process Rate 10^3 bbl/d	Heat Input Rate MW	Heat Input Rate 10^6 Btu/hr	O_2 %, Dry	CO_2 %, Dry	NO ppm*	NO ng/J	NO_x ppm*	NO_x ng/J	CO ppm*	SO_2 ppm*	Flue Gas Radiant Out Temp. K	Flue Gas Radiant Out Temp. °F	Heater† Eff. %	Comb. Air Flow % of Total North	Comb. Air Flow % of Total South	Comments
6/1-1	12-8	132	20	9.09	31.0	4.8	8.2	108	54.9	109	55.4	9	11	969	1285	68.04	51.7	48.3	As found, 100% capacity, Site 6
6/1-2	12-8	132	20	9.60	32.8	4.1	8.1	103	52.3	106	53.8	9	0	986	1315	67.05	51.9	48.1	Baseline
6/1-3	12-8	132	20	9.75	33.2	3.2	9.7	97	49.3	97	49.3	8	0	997	1335	69.08	51.6	48.4	Low O_2
6/1-4	12-8	132	20	9.75	33.2	2.9	14.0	91	46.2	97	49.3	8	17	989	1321	73.33	52.4	47.6	Minimum O_2
6/2-1	12-8	132	20	9.69	33.1	2.5	13.6	87	44.2	93	47.2	6	21	993	1327	73.00	54.5	45.5	Lowered air to S side, min. O_2
6/3-1	12-8	132	20	9.60	32.8	2.7	14.6	44	22.4	--	--	108	21	1001	1342	73.31	48.2	51.8	Lowered air to N side, min. O_2
6/3-2	12-8	132	20	9.39	32.1	2.5	14.4	42	21.3	44	22.4	29	20	993	1327	73.47	47.4	52.6	Lowered air to N side, min. O_2
6/4-1	12-12	106	16	8.20	28.0	2.4	11.0	55	27.9	57	29.0	15	23	986	1315	70.77	46.2	53.8	Minimum O_2, 80% capacity
6/4-2	12-12	106	16	8.14	27.7	2.5	11.4	52	26.4	54	27.4	18	16	982	1307	71.34	46.2	53.8	Minimum O_2
6/4-3	12-12	106	16	8.05	27.5	2.3	11.6	50	25.4	53	26.9	17	14	984	1312	71.44	46.7	53.3	Minimum O_2
6/5-1	12-12	106	16	8.05	27.5	3.5	11.4	75	38.1	79	40.1	11	17	983	1309	71.28	46.5	53.5	Low O_2
6/5-2	12-12	106	16	8.10	27.6	4.1	10.2	96	48.8	101	51.3	11	23	979	1303	70.11	50.0	50.0	Baseline
6/5-3	12-12	106	16	8.29	28.3	4.8	9.9	114	57.9	122	62.0	11	13	978	1301	69.79	49.6	50.4	Medium-high O_2, normal O_2
6/5-4	12-12	106	16	8.84	30.2	5.7	9.4	139	70.6	148	75.2	0	20	985	1313	68.88	50.0	50.0	High O_2
6/5-5	12-12	106	16	8.59	29.4	3.3	11.4	84	42.7	85	43.2	10	15	982	1308	71.45	47.2	52.8	Low O_2
7/1-1	12-16	96	14.5	10.2	34.7	5.3	9.4	130	65.8	--	--	11	20	998	1336	68.00	51.1	48.9	As found, 72.5% capacity, Site 7
7/1-2	12-16	95	14.3	10.2	35.0	4.1	10.8	112	56.7	--	--	21	16	1003	1345	69.50	50.6	49.4	Baseline
7/1-3	12-16	96	14.5	10.4	35.6	3.0	10.0	86	43.5	--	--	20	17	1016	1368	68.06	50.8	49.2	Low O_2
7/1-4	12-16	95	14.3	10.1	34.6	2.6	10.2	86	43.5	--	--	29	14	1019	1374	68.20	50.3	49.7	Minimum O_2
7/1-5	12-16	95	14.3	10.2	34.9	4.2	10.0	118	59.7	--	--	21	16	1002	1343	68.65	50.8	49.2	Baseline
7/2-1	12-16	96	14.5	10.3	35.1	4.0	9.2	98	49.6	101	51.1	31	13	1008	1355	67.29	55.2	44.8	Lowered air to S side
7/2-2	12-16	95	14.3	10.3	35.1	2.3	10.4	70	35.4	74	37.5	33	18	1015	1367	68.52	53.7	46.3	Lowered air to S side, min. O_2
8/1-1	12-17	99	15.0	6.55	22.4	7.7	6.9	148	74.9	153	77.4	14	20	958	1265	65.42	45.8	54.2	As found, 75% capacity, Site 8
8/1-2	12-17	97	14.7	6.37	21.7	5.1	9.1	98	49.6	99	50.1	14	23	982	1300	68.20	48.8	51.2	Baseline
8/1-3	12-17	99	15.0	6.50	22.2	3.8	10.2	81	41.0	85	43.0	15	23	993	1327	69.20	54.7	45.3	Min. O_2, lowered air to S side
8/1-4	12-17	93	14.0	6.46	22.0	5.1	9.6	100	50.6	104	52.6	16	19	984	1312	68.80	56.0	44.0	Normal O_2, lowered air to S side
9/1-1	12-17	97	14.7	4.97	17.0	6.2	8.4	119	60.2	122	61.8	0	18	1002	1343	66.35	49.7	50.3	As found, 73.5% capacity, Site 9
9/1-2	12-17	93	14.0	4.50	15.4	4.0	10.0	75	38.0	76	38.5	11	13	1002	1344	68.70	49.3	50.7	Baseline
9/1-3	12-17	96	14.5	4.50	15.4	3.3	10.2	65	32.9	66	33.4	10	10	1006	1350	68.78	47.1	52.9	Minimum O_2
9/1-4	12-17	97	14.7	4.47	15.3	4.2	9.9	73	37.0	74	37.5	11	10	1002	1343	68.57	45.6	54.4	Normal O_2, lowered air to N side
9/1-5	12-17	97	14.7	4.47	15.3	3.8	9.9	71	35.9	71	35.9	13	15	1004	1348	68.45	47.6	52.4	Low O_2, lowered air to N side
9/1-6	12-17	93	14.1	4.50	15.4	6.5	8.1	114	57.7	118	59.7	12	15	987	1317	66.46	50.3	49.7	High O_2
10/1-1	12-18	187	28.3	7.64	26.1	6.7	8.0	102	51.6	107	54.2	13	12	526	486	73.10§	--	--	As found, 95% capacity, Site 10
10/1-2	12-18	187	28.3	7.64	26.1	3.8	10.2	82	41.5	85	43.0	10	13	547	525	73.95§	--	--	Baseline
10/1-3	12-18	187	28.3	7.64	26.1	1.8	11.2	51	25.8	52	26.3	150	14	544	520	74.63§	--	--	Minimum O_2
10/1-4	12-18	187	28.3	7.62	26.0	2.8	10.4	65	32.9	66	33.4	10	12	544	519	74.41§	--	--	Medium-Low O_2

*Dry, corrected to 3% O_2

†Radiant section only

§Radiant and convection sections included

TABLE 3-4. REFINERY GAS ANALYSES FOR SITES 6-10

Species	Sample date: 12-8-80 Typ. for all tests, Site 6 Volume %	Sample date: 12-16-80 Typ. for all tests, Sites 7-10 Volume %
CO_2	0.5	0.4
N_2 + CO	2.9	3.3
H_2	15.6	18.8
Methane	48.9	50.1
Ethylene	8.7	8.2
Ethane	14.0	13.0
Propylene	5.4	3.1
Propane	2.7	1.6
Butylene	0.3	0.6
Isobutane	0.4	0.3
Normal Butane	0.1	0.2
Pentanes	0.5	0.4
HHV, kJ/m^3 (Btu/ft^3)	43,183 (1159)	40,202 (1079)
K_{NO_x}[ng/J = (ppm @ 3% O_2/K_{NO_x})]	1.969	1.976

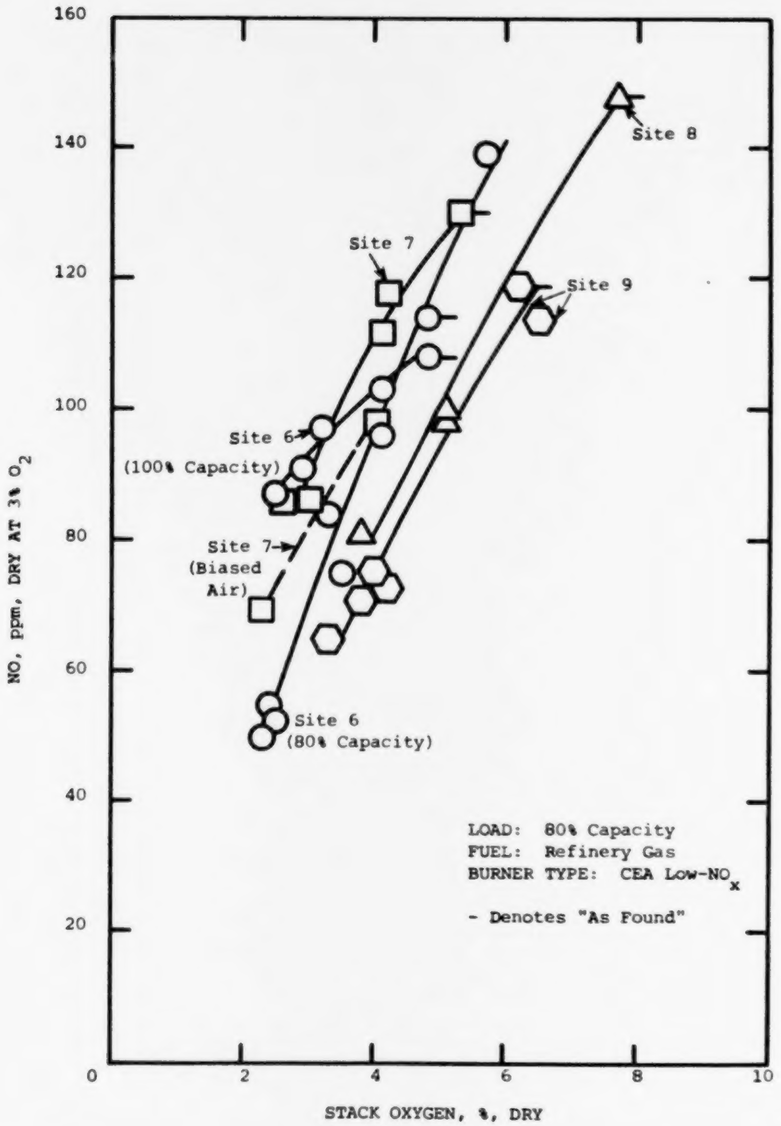

Figure 3-3. NO emissions as a function of stack oxygen for four balanced draft heaters with air preheat firing refinery gas.

The debutanizer bottoms reboiler test results are plotted in Figure 3-4. Once again a sharp dependence of NO emissions on oxygen is exhibited. The forced draft unit was found to be operating at about 7 percent O_2 with NO emissions of 102 ppm, dry at 3 percent O_2. Optimum firing conditions occurred at about 3 percent O_2 with resulting NO emissions of 65 ppm. Below this O_2 level, CO emissions began to increase significantly. At 1.8 percent O_2, the NO level dropped to 51 ppm but CO emissions rose to 150 ppm, dry at 3 percent O_2.

3.2 DISTILLATE-OIL-FIRED, NATURAL DRAFT PROCESS HEATER

Site 2 was a vertical cylindrical crude process heater. The heater had a maximum capacity of 33.12 m^3/h (5000 bbl/day) of process crude oil. The maximum firing rate was 4.4 MW (15×10^6 Btu/hr). The unit was natural draft and utilized a low-NO_x, natural draft burner which fired Number 2 distillate oil and was steam atomized. A fuel analysis for this site is provided in Table 3-5.

As is common with many older heaters, this unit had no tube banks across its "convective" section. The result was stack temperatures in excess of 880K (1125°F). Additionally, because the pressure drop was so low across this heater, fluctuations in combustion air levels would occur every few seconds, depending upon local wind conditions.

The controls were merely adequate for operation. There were pressure gauges for the inlet and outlet crude flows, atomizing steam, and also fuel oil delivery. There was also a temperature gauge on the process crude outlet, along with a thermocouple on the fuel controller downstream of the header.

The heater was operating at full capacity for the entire duration of the tests. The initial tests were excess air survey tests with all burner registers 100 percent open. Following the excess air survey, air register adjustments were systematically performed to determine the effect on NO emissions. All emission measurements were made at the stack.

Although conditions fluctuate widely on this heater, some very encouraging results were obtained. The reduction of NO emissions from the average

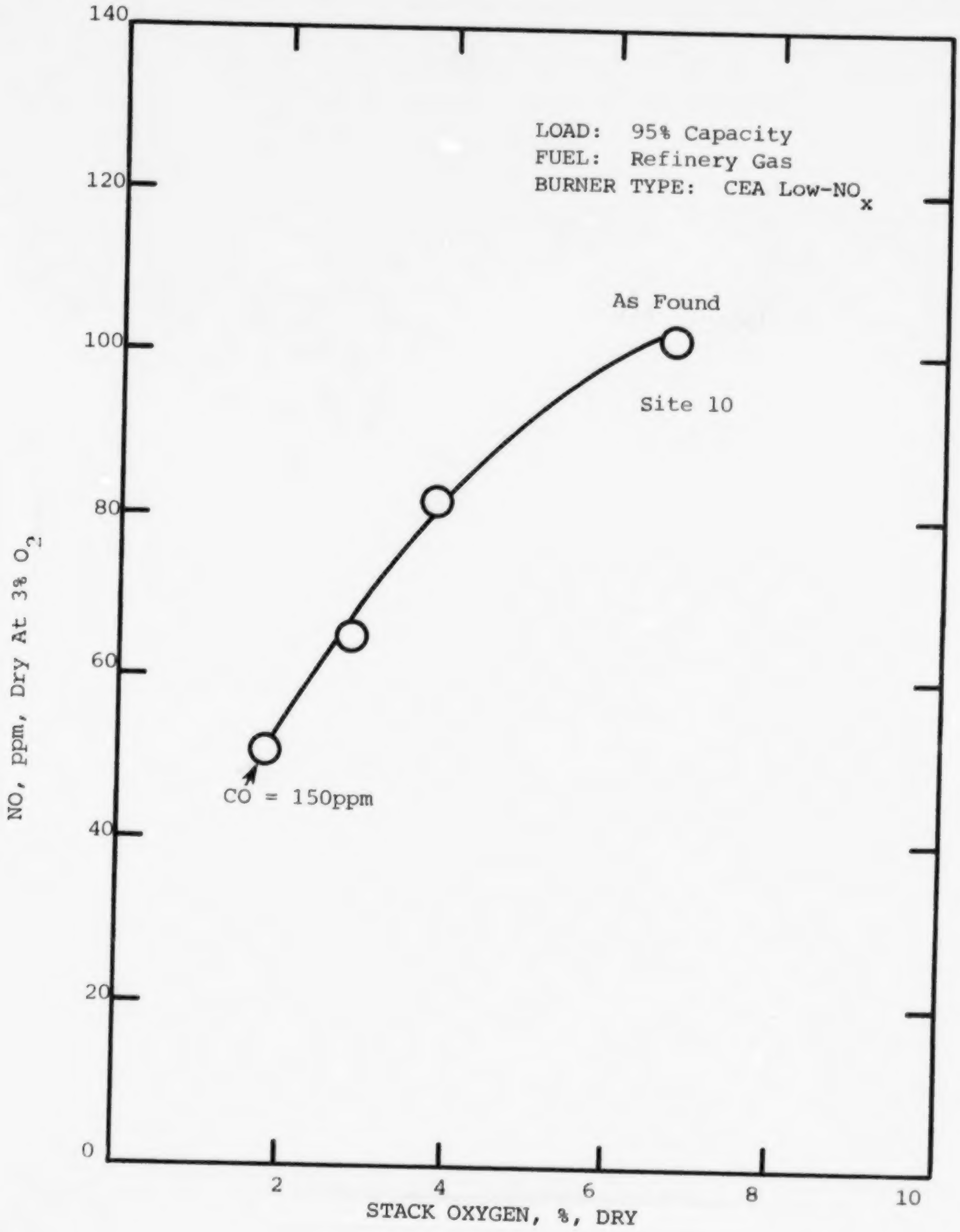

Figure 3-4. NO emissions as a function of stack oxygen for a forced draft heater firing refinery gas.

TABLE 3-5. FUEL ANALYSIS, OIL FUEL, TEST SITE 2

Ultimate Analysis:		
Carbon, %		85.74
Hydrogen, %		12.02
Nitrogen, %		0.15
Sulfur, %		0.69
Ash, %		0.003
Oxygen, % (by difference)		1.40
Heat of Combustion:		
Gross kJ/kg (Btu/lb)	44,194	(19,000)
Net kJ/kg (Btu/lb)	41,635	(17,900)
K_{NO_x}[1]		1.819

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[1] $ng/J = (ppm\ @\ 3\%\ O_2)/K_{NO_x}$

as-found baseline condition (192 ppm) was 48 percent at the CO limit (2.8 percent excess O_2, 237 ppm CO) and 46 percent at close to the optimum operating condition (3.1 percent excess O_2, 40 ppm CO). Also, by adjusting the air registers from the baseline configuration to the low NO_x configuration the stack temperature was reduced from 889K (1140°F) to 839K (1050°F). This gives an increase in efficiency of 3.3 percent. The summary of data is found in Table 3-6 and Figure 3-5.

When the low NO_x mode was used, the outlet process fluid temperature was actually slightly increased. The low NO_x configuration gave a 616K (650°F) outlet crude temperature. The baseline configuration produced a 604K (628°F) outlet crude temperature.

The SO_2 emissions varied from 200 to 445 ppm (wet, as measured). This produces an average of 343 ppm.

Since the unit had very wide fluctuations in load, the measured O_2 was also unsteady. The beginning as-found conditions produced O_2 readings of 5.1, 6.6, and 8.1 percent. A median reading of 6.6 percent was used in determining the baseline condition.

Thus, by observing Figure 3-5 it can be seen that the data fall on one curve quite closely. The "high NO_x" configurations with reduced tertiary air (represented by hexagonal points) did, however, fall above the curve. The points represented by triangles are produced only by a reduction of primary air. These points also fall slightly above the curve produced by the majority of data. By reducing both the primary and secondary air, the emissions are reduced, as shown by the curve.

Additionally, the outlet process fluid temperature for a given process rate seemed to respond favorably. As the low NO_x mode of firing is employed, the heat flux is distributed more evenly through the heater. Furthermore, stack temperatures were decreased, mostly because of the decreased excess air, along with the different localized heat flux. This also increases the efficiency from mid-baseline by 3.3 percent.

TABLE 3-6. SUMMARY OF EMISSIONS AND OPERATING CONDITIONS FOR SITE 2

Test No.	Date 1980	Process Rate		Heat Input		O_2 %, Dry	CO_2 %, Dry	NO		CO ppm*	SO_2 Wet As Meas. ppm	Stack Temp.		Heater Eff. %	Air Registers % Open			Process Fluid °F	Comments
		m³/h	bbl/d	MW	10^6 Btu/hr			ppm*	ng/J			K	°F		Pri.	Sec.	Ter.		
2/1-1a	10-22	33.12	5,000	4.49	15.3	5.1	11.4	168	92.4	11	290	883	1130	63.99	100	100	100	642	Baseline, as found
2/1-1f	10-22	33.12	5,000	--	--	6.6	9.0	196	107.8	13	235	--	--	--	100	100	100	628	Baseline, as found
2/1-1g	10-22	33.12	5,000	--	--	8.1	8.0	212	116.6	0	200	--	--	--	100	100	100	609	Baseline, as found
2/2-1a	10-22	33.12	5,000	--	--	4.5	11.8	165	90.7	11	345	--	--	--	50	100	100	639	Primary air adjustment
2/2-1b	10-22	33.12	5,000	--	--	5.7	11.4	191	105.0	12	290	--	--	--	50	100	100	649	Primary air adjustment
2/3-1a	10-22	33.12	5,000	--	--	3.6	12.2	124	68.2	559	445	--	--	--	50	50	100	710	Primary + secondary air adjustment
2/3-1b	10-22	33.12	5,000	--	--	5.8	10.2	184	101.2	12	300	--	--	--	50	50	100	640	Primary + secondary air adjustment
2/4-1a	10-22	33.12	5,000	--	--	4.8	11.0	178	97.9	11	350	--	--	--	50	100	15	632	Primary + tertiary air adjustment
2/4-1b	10-22	33.12	5,000	4.03	13.8	3.7	12.0	163	89.6	31	370	811	1000	68.79	50	100	15	635	Primary + tertiary air adjustment
2/3-1c	10-22	33.12	5,000	--	--	3.6	12.2	129	70.9	103	440	--	--	--	50	50	100	642	Primary + secondary air adjustment
2/1-3a	10-23	33.12	5,000	4.31	14.7	4.0	11.6	145	80.4	11	270	889	1140	64.04	100	100	100	634	Baseline
2/1-3b	10-23	33.12	5,000	--	--	4.1	11.8	141	78.2	11	360	--	--	--	100	100	100	639	Baseline
2/8-1a	10-23	33.12	5,000	--	--	3.1	12.8	105	58.2	40	400	--	--	--	50	70	100	646	Primary + secondary air adjustment
2/8-1b	10-23	33.12	5,000	--	--	2.8	13.2	101	56.0	237	420	--	--	--	50	70	100	650	Primary + secondary air adjustment
2/8-1c	10-23	33.12	5,000	4.44	15.2	4.1	12.0	147	81.5	21	390	839	1050	67.29	50	70	100	650	Primary + secondary air adjustment
2/1-4b	10-23	33.12	5,000	--	--	4.2	12.0	152	84.3	11	380	--	--	--	100	100	100	643	Baseline

*Corrected to 3% O_2, dry

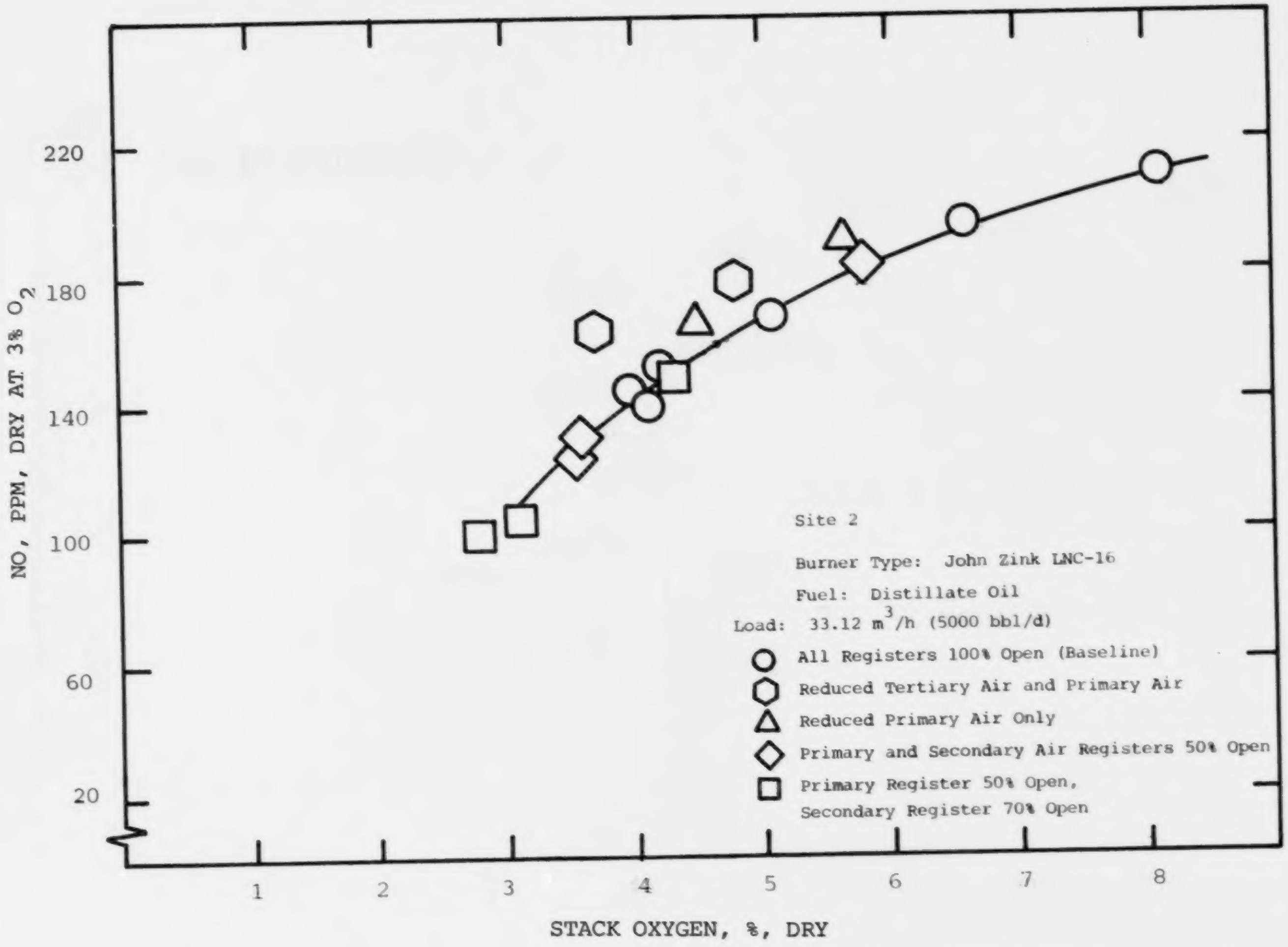

Figure 3-5. NO emission as a function of stack oxygen for a distillate-oil-fired, natural draft process heater.

3.3 RESIDUAL-OIL-FIRED, NATURAL DRAFT HEATERS

Sites 3 and 4 of this project were each natural-draft heaters firing No. 6 oil. An analysis of the oil fired at both sites is given in Table 3-7.

3.3.1 Low-NO_x Burner - Site 3

The natural draft process heater tested at Site 3 was a horizontal heater rated at 106 m^3/h (16,000 bbl/day). The unit was equipped with 12 steam atomized John Zink LNC-12 burners with a maximum rating of 0.97 MW (3.3×10^6 Btu/h) per burner. Figure 3-6 shows a schematic of the heater and burner arrangement. The burners fired horizontally toward the center of the heater.

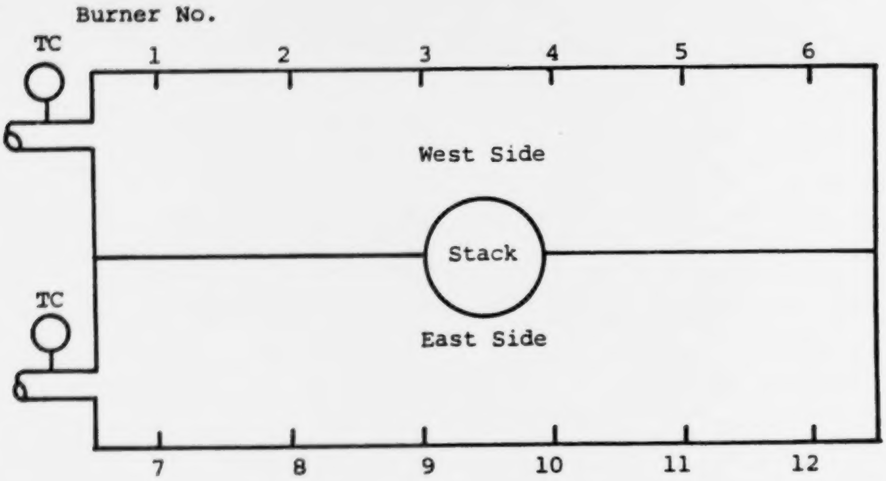

Figure 3-6. Burner arrangement on process heater at Site 3.

During the test series the heater was operating at 84 percent of rated capacity (~13,500 bbl/day). The initial tests were conducted in the "as found" condition with an O_2 range of 4.6 to 5.2 percent. Then the registers of the burners were adjusted in steps to reduce O_2.

TABLE 3-7. FUEL ANALYSIS, NO. 6 OIL FUEL, TEST SITES 3 AND 4

Ultimate Analysis:	
Carbon, %	85.87
Hydrogen, %	11.13
Nitrogen, %	0.81
Sulfur, %	1.11
Ash, %	0.027
Oxygen, % (by difference)	1.05
Heat of Combustion:	
Gross kJ/kg (Btu/lb)	43,100 (18,530)
Net kJ/kg (Btu/lb)	40,751 (17,520)
API Gravity @ 60°F	12.7
K_{NO_x} [ng/J = (ppm @ 3% O_2)/K_{NO_x}]	1.783

Table 3-8 shows a summary of gaseous emissions, heater efficiency and register settings for the individual test data points. All test data points are plotted in Figure 3-7 which shows NO emission versus stack oxygen.

3.3.2 Low NO_x Burner - Site 4

The vertical cylindrical natural draft process heater at Site 4 had a product capacity of 99 m^3/h (15000 bbl/d) It was equipped with three John Zink LNC-16 low NO_x burners. The burners were steam atomized oil burners with a maximum rating of 2.24 MW (7.64 x 10^6 Btu/h).

The first tests were conducted in the "as found" condition with both stack dampers wide open and a process load of 90 m^3/h (13600 bbl/d). At this condition the heater was operating at an oxygen level between 8.1 and 11.4 percent. The oxygen level was reduced while adjusting the two stack dampers. Following the stack damper adjustment test, the burner registers were set for optimum flame appearance. A particulate test was conducted at a slightly higher load setting. This load was required by plant operations. All test results including the particulate test are tabulated in Table 3-9. Figure 3-8 shows the NO emission data points as a function of stack oxygen.

3.4 COMBINATION OIL/GAS-FIRED, NATURAL DRAFT PROCESS HEATER

The process heater at Site 5 was a vertical, rectangular, natural draft heater rated at 92.7 m^3/h (14000 bbl/d). It was equipped with ten John Zink LNC-PC-10 low-NO_x burners. Each burner was rated at 1.2 MW (4 x 10^6 Btu/hr). The fuel used during our test program was a combination of No. 6 oil and refinery gas. A gas and oil sample were analyzed and the results are presented in Tables 3-10 and 3-11.

The heater was first tested in the "as found" condition with all air registers 100 percent open. The stack damper was then adjusted gradually in steps to reduce oxygen. Following the excess air test, the burner registers were adjusted. During all these tests the heater process rate and the oil and gas ratio were held constant.

Table 3-12 shows a summary of gaseous and particulate emissions, heater efficiency, fuel split, and register settings for the individual test data points. Figure 3-9 is a plot of NO emission as a function of oxygen.

TABLE 3-8. SITE 3, SUMMARY OF GASEOUS EMISSION AND EFFICIENCY FOR A NATURAL DRAFT PROCESS HEATER EQUIPPED WITH LOW-NO_x BURNERS

Test No.	Date 1980	Process Rate		Heat Input†		O_2 %, Dry	CO_2 %, Dry	NO		CO ppm*	SO_2 Wet As Meas. ppm	Stack Temperature		Heater Eff. %	Product Outlet Temp. °F	BOOS** No.	Air Registers % Open			Stack Damper % Open	Comments
		m^3/h	bbl/d	MW	10^6 Btu/hr			ppm*	ng/J			K	°F				Pri.	Sec.	Ter.		
3-1	10-28	89.6	13,530	9.8	33	5.2	10.1	396	222	11	758	905	1170	63.4	662	1	85	86	81	90	As found
3-2	10-28	88.9	13,416	9.8	33	4.6	11.5	401	225	11	530	905	1170	64.4	663	1	85	86	81	90	As found
3-3	10-28	89.6	13,530	9.8	33	4.3	11.1	361	203	11	340	922	1200	64.5	663	1 & 7	57	65	69	90	Register adjust.
3-4	10-28	89.6	13,530	9.8	33	5.3	10.3	385	216	11	560	922	1200	62.5	660	1 & 7	57	65	69	90	Flame adjustment
3-5	10-29	89.6	13,530	9.8	33	5.2	10.6	369	207	11	425	900	1160	63.8	648	1 & 7	54	58	66	90	Register adjust.
3-6	10-29	89.6	13,530	9.8	33	5.3	11.4	377	211	11	430	900	1160	63.7	653	1 & 7	54	58	66	90	Register adjust.

*Corrected to 3% O_2, dry

**Registers closed on BOOS

†Estimated from % capacity; no fuel flowmeter available

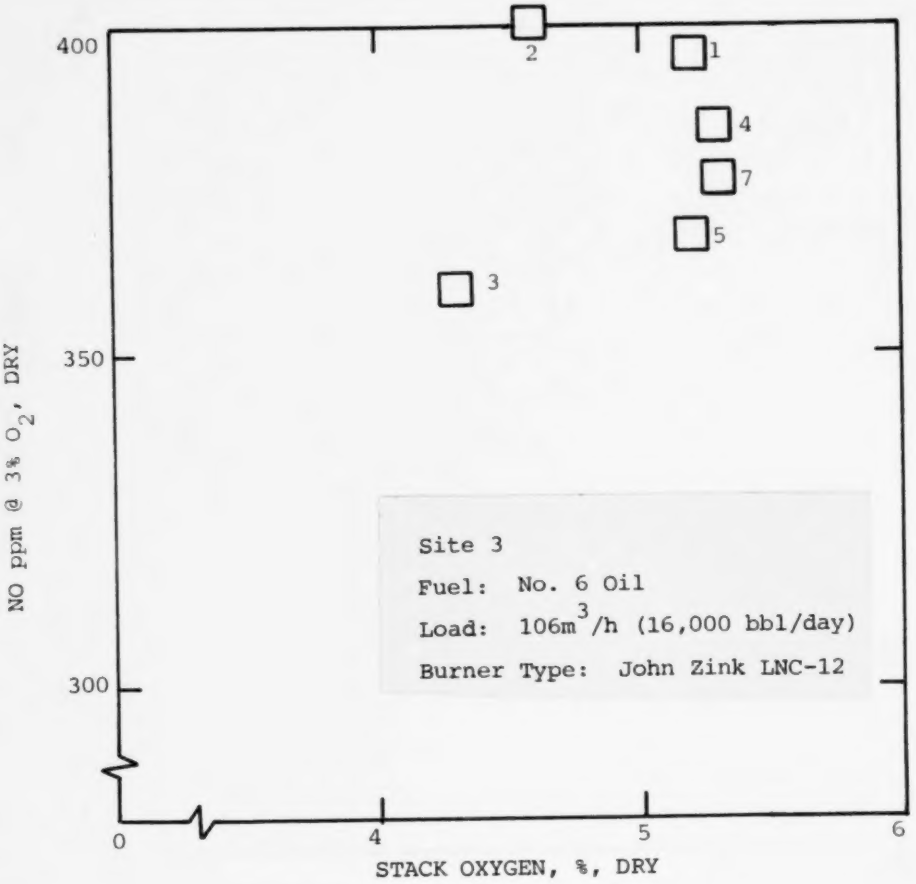

Figure 3-7. NO emission as a function of oxygen for a residual-oil-fired natural draft process heater.

TABLE 3-9. SITE 4. SUMMARY OF GASEOUS EMISSIONS AND EFFICIENCY FOR A NAUTRAL DRAFT PROCESS HEATER EQUIPPED WITH LOW-NO_x BURNERS

Test No.	Date 1980	Process Rate		Heat Input†		O_2 %, Dry	CO_2 %, Dry	NO		CO ppm*	SO_2 Wet As Meas. ppm	Stack Temperature		Heater Eff. %	Product Outlet Temp. °F	Air Registers % Open			Stack Damper % Open N/S††	Solid Particulate		Comments
		m^3/h	bbl/d	MW	10^6 Btu/hr			ppm*	ng/J			K	°F			Pri.	Sec.	Ter.		$lb/10^6$ Btu	ng/J	
4-1	10-29	89.9	13,600	6.09	20.8	8.1	7.4	477	268	0	425	733	860	67.9	702	87	87	87	100/100			As found
4-2	10-30	89.9	13,600	6.09	20.8	11.4	6.2	506	284	19	410	694	790	62.6	695	83	87	87	100/100			As found
4-3	10-30	89.9	13,600	6.09	20.8	7.6	9.2	466	261	13	455	753	895	67.7	703	83	87	87	20/100			Stack damper adjustment
4-4	10-30	89.9	13,600	6.09	20.8	7.1	8.6	471	264	0	450	744	880	68.6	696	60	67	83	20/100			Register adjustment
4-5	10-30	89.3	13,500	6.04	20.6	7.8	9.7	504	283	0	340	755	900	67.0	698	60	67	83	20/100			Register adjustment
4-6	10-30	88.0	13,300	5.95	20.3	6.9	10.2	478	268	13	370	753	895	68.8	704	50	50	73	20/100			Register adjustment
4-7	11-4	95.9	14,500	6.49	22.2	11.5	5.6	496	278	0	310	712	822	61.3	695	50	60	80	20/100	0.1680	72.24	Particulate test high load

*Corrected to 3% O_2, dry

†Estimated from % capacity; no fuel flowmeter available

††N = North Damper; S = South Damper

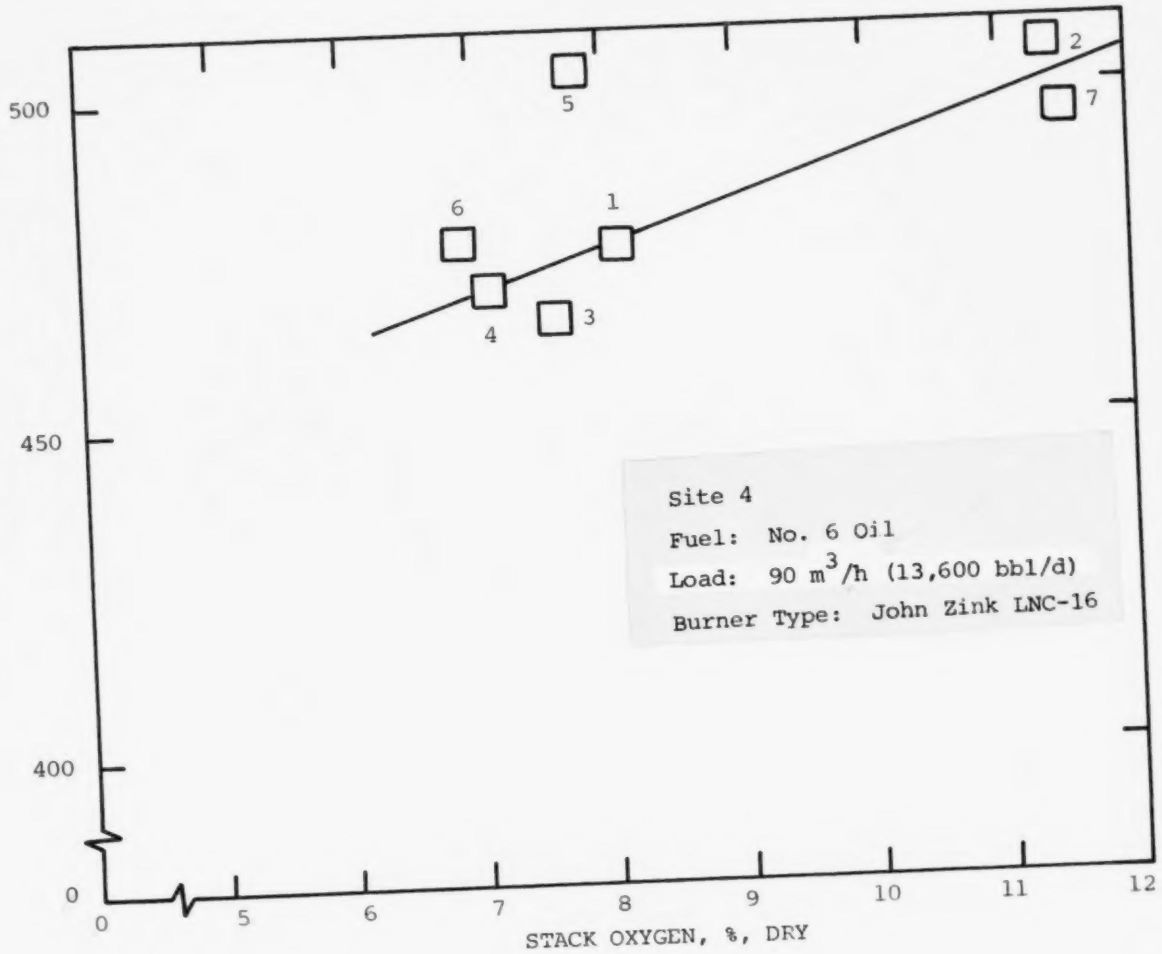

Figure 3-8. NO emission as a function of oxygen for a residual-oil-fired natural draft process heater.

TABLE 3-10. FUEL ANALYSIS, OIL FUEL, TEST SITE 5

Ultimate Analysis:	
Carbon, %	85.92
Hydrogen, %	11.34
Nitrogen, %	0.81
Sulfur, %	1.00
Ash, %	0.043
Oxygen, % (by difference)	0.89
Heat of Combustion:	
Gross Btu/lb	18,530
Net Btu/lb	17,500
API Gravity @ 60°F	14.5
K_{NO_x} [ng/J = (ppm @ 3% O_2)/K_{NO_x}]	1.791

TABLE 3-11. FUEL ANALYSIS, REFINERY GAS, TEST SITE 5

CHROMATOGRAPHIC ANALYSIS

COMPONENT	MOLE PERCENT
Nitrogen + Oxygen	1.400
Carbon Dioxide	0.557
Methane	1.244
Ethane	7.068
Propylene	0.000
Propane	54.749
Isobutane	18.137
N-Butane	15.139
Isopentane	0.516
N-Pentane	0.448
Hexanes-Plus	0.742
TOTAL	100.00
Gross Heat of Combustion 100,301 kJ/m^3 (2692 Btu/ft^3)	
Specific Gravity	1.6865
K_{NO_x} [ng/J = (ppm @ 3% O_2)/K_{NO_x}]	1.938

TABLE 3-12. SITE 5. SUMMARY OF GASEOUS EMISSION AND EFFICIENCY FOR A NATURAL DRAFT PROCESS HEATER EQUIPPED WITH LOW-NO_x BURNERS

Test No.	Date 1980	Process Rate		Heat Input		Fuel Split % of Heat Input		O_2 %, Dry	CO_2 %, Dry	NO		CO ppm*	SO_2 Wet As Meas. ppm	Stack Temp.		Air Registers % Open			Solid Partic.		Comments
		m^3/h	bbl/d	MW	10^6 Btu/hr	No. 6 Oil	Ref. Gas			ppm*	ng/J			K	°F	Pri.	Sec.	Ter.	lb/10^6 Btu	ng/J	
5-1	11-7	59.75	9,020	11.98	40.9	84	16	7.6	8.8	347	192	13	310	769	924	100	100	100			As found
5-2	11-7	60.26	9,100	11.34	38.7	83	17	7.8	8.4	355	196	14	280	767	920	100	100	100			As found
5-3	11-10	60.26	9,100	11.08	37.8	82	18	7.7	8.6	352	194	11	300	767	920	100	100	100			As found
5-4	11-10	59.75	9,020	10.75	36.7	82	18	6.9	9.6	345	190	11	340	759	906	100	100	100			Stack damper adjustment
5-5	11-10	59.75	9,020	10.11	34.5	81	19	5.7	10.6	335	185	12	390	744	879	100	100	100			Stack damper adjustment
5-6	11-10	59.75	9,020	9.82	33.5	81	19	4.4	11.8	303	167	22	415	730	854	100	100	100			Stack damper adjustment
5-7	11-10	59.75	9,020	11.22	38.3	84	16	7.6	9.0	359	198	11	338	759	907	100	100	100			As found
5-8	11-11	59.75	9,020	11.75	40.1	85	15	8.0	8.6	366	202	11	340	767	921	100	100	100			As found
5-9	11-11	59.75	9,020	11.40	38.9	85	15	8.1	8.8	358	198	7	340	762	911	65	72	100			Register adjustment
5-10	11-11	59.75	9,020	11.19	38.2	84	16	7.2	9.2	329	182	7	360	754	897	60	59	76			Register adjustment
5-11	11-11	59.75	9,020	11.22	38.3	84	16	6.3	10.0	331	183	6	365	749	888	60	59	76			Register + damper adjustment
5-12	11-11	59.75	9,020	11.22	38.3	84	16	6.4	10.0	333	184	10	380	755	899	100	100	100			Stack damper adjustment
5-13	11-12	59.75	9,020	9.67	33.0	61	39	7.4	8.0	289	156	8	220	776	937	100	100	100			As found
5-14	11-12	59.75	9,020	8.79	30.0	57	43	5.9	8.4	259	139	20	245	764	916	100	100	100	0.0605	26.01	Particulate Test - stack damper adjustment

*Corrected to 3% O_2, dry

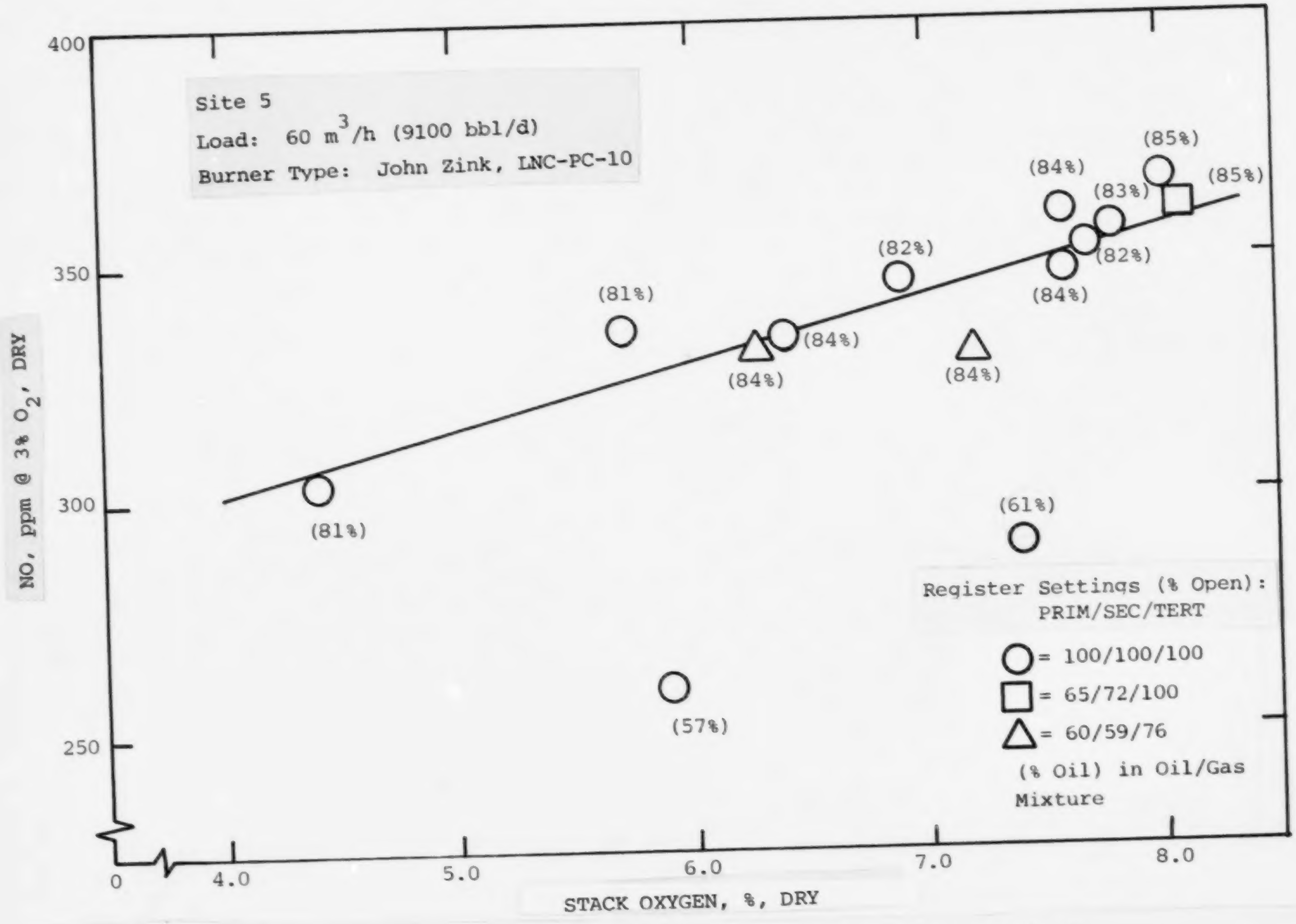

Figure 3-9. NO emissions as a function of oxygen for a natural draft process heater firing a combination of residual oil and refinery gas.

SECTION 4.0

REFERENCES

1. Hunter, S. C. et al., "Application of Advanced Combustion Modifications to Industrial Process Equipment, Interim Report," prepared for the U.S. EPA Industrial Environmental Research Laboratory under Contract No. 68-02-2645, Research Triangle Park, N.C., not yet published.

2. Hunter, S. C. and Cherry, S. S., $\underline{NO_x}$ Emissions from Petroleum Industry Operations, API Publication No. 4311, American Petroleum Institute, Washington, D.C., October 1979.

APPENDIX A

CONVERSION FACTORS

CONVERSION FACTORS

SI Units to Metric or English Units

To Obtain	From	Multiply By
g/Mcal	ng/J	0.004186
10^6 Btu	GJ	0.948
Btu	gm cal	$3.9685\text{x}10^{-3}$
lb/10^6 Btu	ng/J	0.00233
ft	m	3.281
in.	cm	0.3937
ft^2	m^2	10.764
ft^3	m^3	35.314
lb	kg	2.205
Fahrenheit	Celsius	$t_F = 9/5(t_c) + 32$
Fahrenheit	Kelvin	$t_F = 1.8t_K - 460$
psig	Pa	$P_{psig} = (P_{pa})(1.450\text{x}10^{-4})-14.7$
psia	Pa	$P_{psia} = (P_{pa})(1.450\text{x}10^{-4})$
iwg (39.2 °F)	Pa	$P_{iwg} = (P_{pa})(4.014\text{x}10^{-3})$
10^6 Btu/hr	MW	3.413
GJ/hr	MW	3.60

To Obtain ppm at 3% O_2 of	Multiply* Concentration in ng/J by
Natural Gas Fuel	
CO	3.23
HC	5.65
NO or NO_x	1.96
SO_2 or SO_x	1.41
Oil Fuel	
CO	2.93
HC	5.13
NO or NO_x	1.78
SO_2 or SO_x	1.28
Coal Fuel	
CO	2.69
HC	4.69
NO or NO_x	1.64
SO_2 or SO_x	1.18

*These conversions depend on fuel composition. The values given are for typical fuels.

English and Metric Units to SI Units

To Obtain	From	Multiply By
ng/J	lb/10^6 Btu	430
ng/J	g/Mcal	239
GJ	10^6 Btu	1.055
m	ft	0.3048
cm	in.	2.54
m^2	ft^2	0.0929
m^3	ft^3	0.02832
kg	lb	0.4536
Celsius	Fahrenheit	$t_C = 5/9\ (t_F - 32)$
Kelvin	Fahrenheit	$t_K = 5/9\ (t_F - 32) + 273$
Pa	psig	$P_{pa} = (P_{psig} + 14.7)(6.895 \times 10^3)$
Pa	psia	$P_{pa} = (P_{psia})(6.895 \times 10^3)$
Pa	iwg (39.2 °F)	$P_{pa} = (P_{iwg})(249.1)$
MW	10^6 Btu/hr	0.293
MW	GJ/hr	0.278

To Obtain ng/J of	Multiply* Concentration in ppm @ 3% O_2 by
Natural Gas Fuel	
CO	0.310
HC	0.177
NO or NO_x (as NO_2)	0.510
SO_2 or SO_x	0.709
Oil Fuel	
CO	0.341
HC	0.195
NO or NO_x (as NO_2)	0.561
SO_2 or SO_x	0.780
Coal Fuel	
CO	0.372
HC	0.213
NO or NO_x (as NO_2)	0.611
SO_2 or SO_x	0.850

*These conversions depend on fuel composition. The values given are for typical fuels.

APPENDIX B

DATA SUPPLEMENT

For each unit tested, the data supplement contains the following information:

1. Equipment Design Data

   Design data tabulations include: unit description, installation date, process capacity, burner description, fuels burned, combustion air temperature and other data pertinent to each unit.

2. Mobile Laboratory Data (Emission Measurements)

   Emission measurements tabulated for each test include test number, test load, combustion conditions (excess O_2, CO_2), gaseous emissions (NO_x, NO, CO, HC, SO_x and SO_2 all at 3% O_2, dry), total particulates and solid (filterable) particulates, thermal efficiency, Bacharach smoke spot number, and plume opacity.

3. Operating Data

   Data pertinent to the process are tabulated for each test.

4. Fuel Analyses

   Analyses of test fuels are included as reported for fuel samples collected during tests.

SITE 1

PETROLEUM PROCESS HEATER

Location No. SITE # 1 **Unit No.**

Unit Description

VERTICAL CYLINDRICAL FORCED DRAFT HEATER

Installation Date N/A

Heater Rating 92.7 $\frac{m^3}{h}$

Burner Description THREE (3) JOHN ZINK LOW NOX LNC-PC-16

Test Fuel Combinations NATURAL GAS & REFINERY OFF-GAS

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) AMBIENT

Comments:

MOBILE LABORATORY DATA Test No.________

Test No. 1-1 Date 10-1-80 Location 1 Engr. Shiau, Tidona

Unit No. F1 Fuel NG + Ref. Gas Capacity 14,000 bbl/d

Unit Type CRUDE HEATER Burner Type JOHN ZINK LO-NOx DBA-PC-16

1. Test No.	1-1		1-2		1-3		1-4		1-5	
2. Date	10-1-80		″		″		″		″	
3. Time	13:30-13:45		14:12 - 14:26		14:47		15 12		15:39	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft	3^{6}		″		″		″		″	
7. Probe Position	CENTER		″		″		″		″	
8. Oxygen (%)	10.5		9.0		3.1		1.9 (1.5-2.0)		5.9 (5.7-6.0)	
9. NOx (hot) read/3% O_2 (ppm)*	42	87	49	87	43	57	37	47	53	79
10. NO (hot) read/3% O_2 (ppm)*	42	87	49	87	43	57	37	47	53	79
11. NO_2 (hot) read/3% O_2 (ppm)*	0	0	0	0	0	0	0	0	0	0
12. NO (cold) read/3% O_2 (ppm)*	51	87	58	67	57	57	50	47	67	79
13. Carbon Dioxide (%)	5.5		6.2		10.6		11.5		9.3	
14. Carbon Monoxide (ppm) uncor/cor	0	0	0	0	20	20	60 (40-70)	57	20	24
15. Hydrocarbon (ppm) uncor/cor*	0.05									
16. Sulfur Dioxide (ppm) uncor/cor*	20		20		20		80		100	
17. Smoke Spot (Bacharach)	—									
18. Atmos. Temp. (°F/°C)	76		74		74		73		73	
19. Dew Point Temp. (°F/°C)	70		70		70		69		70	
20. Atmos. Pressure (in. Hg)	30.20		30.20		30.20		30.20		30.20	
21. Relative Humidity (%)	76		81		81		81		86	
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. 1-6 –

Test No. 1-6 Date 10·2·80 Location 1 Engr. TIMONIS

Unit No. F1 Fuel NG+Ref GAS Capacity 14000 bbl/d

Unit Type CRUDE HTR Burner Type JOHN ZINK LO-NOx

1. Test No.	1-6		1-7		1-8		1-9		1-10	
2. Date	10-2-80		—		—		—		→	
3. Time	10:42		11:05		11:25		11:56		12:36	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	C		C							
8. Oxygen (%)	4.0		4.2		4.2		3.7		4.2	
9. NOx (hot) read/3% O_2 (ppm)*	37	56	40	60	47	64	36	53	37	55
10. NO (hot) read/3% O_2 (ppm)*	37	56	40	60	47	64	36	53	37	55
11. NO_2 (hot) read/3% O_2 (ppm)*	0	0	0	0	0	0	0	0	0	0
12. NO (cold) read/3% O_2 (ppm)*	53	56	55	60	60	64	51	53	51	55
13. Carbon Dioxide (%)	10.0		10.0		10.0		10.3		10.0	
14. Carbon Monoxide (ppm) uncor/cor*	10	11	10	11	10	11	20	21	20	21
15. Hydrocarbon (ppm) uncor/cor*	–	–	–	–	–	–	–	–	–	–
16. Sulfur Dioxide (ppm) uncor/cor*	120	-	130		120	-	120	–	100	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	75		81		79		78		78	
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.24		30.24		30.24		30.24		30.24	
21. Relative Humidity (%)	82		70		72		72		72	
22. AIR REGISTER ADJUSTED	NO		YES		YES		YES		YES	
23. COMD.	BASELINE									
24.	REFIN.		CRUDE							
25.	GAS		TANK							
26.	SAMPLE		SWITCH							
27.	TAKEN									
28.										
29.	BASELINE									
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. 1-6 –

Test No. 1-11, 1-12 Date 10-2-80 Location ________ Engr. TIDONA

Unit No. F1 Fuel NG Capacity 14000 bbl/d

Unit Type Crude HTR Burner Type ZINK lo NOx

1. Test No.	1-11		1-12							
2. Date	10-2-80		→							
3. Time	13:05									
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	c		c							
8. Oxygen (%)	4.0		4.3							
9. NOx (hot) read/3% O_2 (ppm)*	45	64	53	72						
10. NO (hot) read/3% O_2 (ppm)*	45	64	53	72						
11. NO_2 (hot) read/3% O_2 (ppm)*	0	0	0	0						
12. NO (cold) read/3% O_2 (ppm)*	60	64	68	72						
13. Carbon Dioxide (%)	9.6		9.6							
14. Carbon Monoxide (ppm) uncor/cor*	10	11	10	11						
15. Hydrocarbon (ppm) uncor/cor*	–	–	–	–						
16. Sulfur Dioxide (ppm) uncor/cor*	110		100							
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	78		78							
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30,24		30 74							
21. Relative Humidity (%)	72		72							
22.										
23. CONDS	REPEAT									
24.	BASELINE									
25. AIR REGISTER ADJUST	NO		YES							
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. 1-13 —

Test No. 1-13 Date 10-3-80 Location 1 Engr. ZIDONYA

Unit No. F1 Fuel NG+REF GAS Capacity 14000 bbl/d

Unit Type CRUDE HTR Burner Type ZINK LO NOX

1. Test No.	1-13		1-14		1-15		1-16		1-17	
2. Date	10-3-80		→							
3. Time	09:15		09:35		09:52		10:20		11:14	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	C		→							
8. Oxygen (%)	6.2		3.7		2.7		8.5		4.4	
9. NOx (hot) read/3% O_2 (ppm)*	49		46		39		47		52	
10. NO (hot) read/3% O_2 (ppm)*	49		46		39		47		52	
11. NO_2 (hot) read/3% O_2 (ppm)*	0	0	0	0	0	0	0	0	0	0
12. NO (cold) read/3% O_2 (ppm)*	63	77	58	60	55	54	58	83	67	73
13. Carbon Dioxide (%)	8.4		10.2		10.6		6.9		9.6	
14. Carbon Monoxide (ppm) uncor/cor*	0	0	0	0	10	10	0	0	5	5
15. Hydrocarbon (ppm) uncor/cor*	-	-	-	-	-	-	-	-		
16. Sulfur Dioxide (ppm) uncor/cor*	160		160		160		100		135	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	68°		68°		68°		71°		73	
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.28		30.28		30.28		30.28		30.28	
21. Relative Humidity (%)	82		82		82		78		75	
22.										
23. COND:	AS		4%		LOW		HIGH		4%	
24.	FOUND		BASELINE		O_2		O_2		BASELINE	
25.										
26. AIR REGISTER ADJUST	NO		NO		NO		NO		NO	
27.										
28. COMMENTS:									CRUDE	
29.									TANK	
30.									SWITCH	

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. 1-18 —

Test No. 1-18 Date 10-3-80 Location 1 Engr. TIDONA

Unit No. F1 Fuel NG+ REF GAS Capacity 14000 bbl/d

Unit Type CRUDE HTR Burner Type ZINK LO-NOx

1. Test No.	1-18		1-19		1-20		1-21		1-22	
2. Date	10-3-80									
3. Time	11:47		12:12		12:35		12:54		13:17	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	C									
8. Oxygen (%)	4.2		4.4		4.4		4.5		4.5	
9. NOx (hot) read/3% O_2 (ppm)*	48		47		48		45		49	
10. NO (hot) read/3% O_2 (ppm)*	48		47		48		45		49	
11. NO_2 (hot) read/3% O_2 (ppm)*	0	0	0	0	0	0	0	0	0	0
12. NO (cold) read/3% O_2 (ppm)*	65	70	60	65	63	68	58	63	65	71
13. Carbon Dioxide (%)	9.6		9.8		9.8		9.3		9.3	
14. Carbon Monoxide (ppm) uncor/cor*	5	5	0	0	0	0	10	11	5	6
15. Hydrocarbon (ppm) uncor/cor*	—	—	—	—	—	—	—	—	—	—
16. Sulfur Dioxide (ppm) uncor/cor*	140		140		130		140		135	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	74°		75°		74°		74°			
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.29		30,28		30.28		30.26			
21. Relative Humidity (%)	70		67		70		67			
22.									REPEAT	
23. COND:	4 %		4 %		4 %		4 %		4 %	
24.									BASELINE	
25.										
26. AIR REGISTER ADJUST	YES		YES		YES		YES		NO	
27.										
28. COMMENTS:	CLOSED		CLOSED		½ 2nd		CLOSED		—	
29.	PRIMARY		SECONDARY		½ PRIM		PRIMARY			
30.							½ 2nd			

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. 1-23—

Test No. 1-23 Date 10-3-80 Location 1 Engr. TIDOMA

Unit No. F1 Fuel NG + REF Gas Capacity 14000 bbl/d

Unit Type CRUDE HTR Burner Type ZINK LO-NOX

1. Test No.	1-23		1-24							
2. Date	10-3-80		→							
3. Time	13:40		14:07							
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	C		→							
8. Oxygen (%)	4.3		3.0							
9. NOx (hot) read/3% O_2 (ppm)*	53		41							
10. NO (hot) read/3% O_2 (ppm)*	53		41							
11. NO_2 (hot) read/3% O_2 (ppm)*	0	0	0	0						
12. NO (cold) read/3% O_2 (ppm)*	71	77	48	48						
13. Carbon Dioxide (%)	9.6		10.3							
14. Carbon Monoxide (ppm) uncor/cor*	0	0	20	20						
15. Hydrocarbon (ppm) uncor/cor*	—	—	—	—						
16. Sulfur Dioxide (ppm) uncor/cor*	140		155							
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	75		75							
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.28		30.28							
21. Relative Humidity (%)	70		52							
22.										
23. COND%	4%		4%							
24.										
25. AIR REGISTER ADJUST	YES		YES							
26.										
27. COMMENTS	LOW		CLOSED							
28.	TERTIARY		2ndary							
29.	AIR		1/2 PRIM							
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA

Test No._______

Test No. 1-1 to 1-5 Date 10-1-80 Location 1 Engr. Tidona

Unit No. F1 Fuel NG + Ref. Gas Capacity 14,000 bbl/d

Unit Type CRUDE HEATER Burner Type JOHN ZINK LO-NOx, DBA-PC-16

1. Test Number	1-1	1.2	1.3	1-4	1-5
2. Date	10-1-80	10-1-80	10-1-80	10-1-80	10-1-80
3. Time	13:15	14:13	14:48	15:13	15:29
4. Load					
5. Process Rate , bbl/d	8000	8000	8000	8000	8000
6Crude to Fl,Pass A,bbl/d	4400	4400	4400	4400	4400
7Crude to Fl,PassB,bbl/d	3600	3600	3600	3600	3600
8Crude to F2[illegible],bbl/d	1230	1290	1320	1380	1410
9.Offgas Flow	3.0	2.2	2.0	1.8	1.6
10Crude in Temp,Pass A,°F	310	312	310	310	310
11Crude in Temp,Pass B,°F	305	305	305	302	305
12Crude Out Temp.A, °F	430	430	432	436	435
13Crude Out Temp B, °F	430	427	421	423	425
14Stack Temp, °F	435	402	350	321	330 +
15.Conv. Sect. Gas T in °F	685	670	650	639	641
16 Conv. Sect. Crude T Out, A, °F	345	350	335	331	341
17.Conv.Sect. Crude T Out, B, °F	350	350	333	330	340
18Naptha Flow, bbl/d	1125	1100	1150	1075	1075
19.Crude Feed H_2O, %	1.5	0.4	0.4	~0.4	~0.4
20.Tower Press, psig	8.4	7.8	7.6	7.6	7.4
21Crude in Press, B, psig	86	76	76	68	68
22.Natural Gas Flow, Scf×1000	52683 13:27	52691 14:20	52695 14:51	52699 15:17	52702 15:37
23.Crude API Gravity	20.1	20.6	20.6	20.6	20.6
24.FAN INLET DPR, % OPEN	55	35	15	~10	~35
25.OFFGAS ACCUM PRESS, psig	4.3	4.4	4.5	4.5	4.5
26. COMMENTS	AS FOUND	9% O_2	3% O_2	1.5-2.0% O_2 CO limit	med. O_2
27.			lazy flame	Smoking thresh.	
28.					
29.					
30. REFLUX TEMP, °F (or offgas temp.)	105	100	100	100	100

NG Flow (Tests 1-1 to 1-5) = 8769 SCFH

Data Sheet 6002-1

UNIT OPERATING DATA

Test No.

Test No. 1-6 to 1-10 Date 10-2-80 Location 1 Engr. T. dove

Unit No. F1 Fuel NG + Ref. Gas Capacity 14,000 bbl/d

Unit Type CRUDE HEATER Burner Type JOHN ZINK CO. NO_x DBM-PC-16

1. Test Number	1-6	1-7	1-8	1-9	1-10
2. Date	10-2-80	10-2-80	10-2-80	10-2-80	10-2-80
3. Time	10:43	11:06	11:25	11:55	12:32
4. Load					
5. Process Rate , bbl/d	8000	8000	8000	8000	8000
6 Crude to F1, Pass A, bbl/d	4400	4400	4400	4400	4400
7 Crude to F1, PassB, bbl/d	3600	3600	3600	3600	3600
8 Crude to F2(x300), bbl/d	1230	1230	1230	1250	1260
9. Offgas Flow	4.0	4.2	4.2	4.1	4.0
10 Crude in Temp, Pass A, °F	312	310	310	310	310
11 Crude in Temp, Pass B, °F	305	305	305	305	305
12 Crude Out Temp. A, °F	439	436	436	435	432
13 Crude Out Temp B, °F	438	437	435	440	440
14 Stack Temp, °F	370	370	365	361	361
15. Conv. Sect. Gas T in °F	700	690	685	680	670
16 Conv, Sect. Crude T Out, A, °F	331	330	330	330	330
17. Conv. Sect. Crude T Out, B, °F	331	330	330	330	330
18 Naptha Flow, bbl/d	1025	1035	1060	1100	1050
19. Crude Feed H_2O, %	1.2	1.2	1.2	1.0	1.0
20. Tower Press, psig	8.1	8.2	8.0	8.0	8.0
21 Crude in Press, B, psig	78	78	82	82	82
22. Natural Gas Flow, Scf	52868 $^{10:48}$	52870 $^{11:10}$	52872.5 $^{11:31}$	52876 $^{12:04}$	52880 $^{12:41}$
23. Crude API Gravity	20.7	20.7	20.7	20.3	20.3
24. FAN INLET DPR, % OPEN	30	30	30	30	30
25. OFFGAS ACCUM. PRESS., psig	3.6	3.6	3.6	3.6	3.6
26. COMMENTS	BASELINE	ZERO PRIMARY	SEC. AIR 50% OP.	SEC. AIR - 10% OP.	→
27.	PRIM AIR - 60% OP.	AIR	PR. AIR - 100% OP.	→	PR AIR - 50% OP.
28.	SEC AIR - 100% OP.	SEC. AIR - 100% OP.			
29.	TERT. AIR - 100% OP.	TERT. AIR - 100% OP.	→	→	→
30.	flame short + bushy	flame longer,	Short, lazy flame	→	CO limit
	~5'-6' ht.	narrower			poor mixing
Reflux Temp., °F	98	110	110	110	110

Data Sheet 6002-1

NG Flow (Tests 1-6 to 1-10) = 6372 SCFH

UNIT OPERATING DATA

Test No.

Test No. 1-11 Date 10-2-80 Location 1 Engr. Tidma

Unit No. F1 Fuel NG + Ref. Gas Capacity 14,000 bbl/d (11.1 x10⁶ Btu/h)

Unit Type CRUDE HEATER Burner Type Zink LO-NOx DBA-PC-16

1. Test Number	1-11	1-12			
2. Date	10-2-80	10-2-80			
3. Time	13:03	13:38			
4. Load					
5. Process Rate , bbl/d	8000	8000			
6 Crude to F1, Pass A, bbl/d	4400	4400			
7 Crude to F1, PassB, bbl/d	3600	3600			
8 Crude to F2 (~~#200~~), bbl/d	1230	1260			
9. Offgas Flow	4.0	3.8			
10 Crude in Temp, Pass A, °F	310	310			
11 Crude in Temp, Pass B, °F	305	305			
12 Crude Out Temp. A, °F	435	438			
13 Crude Out Temp B, °F	437	431			
14 Stack Temp, °F	365	365			
15. Conv. Sect. Gas T in °F	685	695			
16 Conv, Sect. Crude T Out, A, °F	330	330			
17. Conv. Sect. Crude T Out, B, °F	330	330			
18 Naptha Flow, bbl/d	1030	1075			
19. Crude Feed H_2O, %	1.0	1.0			
20. Tower Press, psig	8.0	7.8			
21 Crude in Press, B, psig	82	82			
22. Natural Gas Flow, Scf	52883 13:10	52886.5 13:45			
23. Crude API Gravity	20.3	20.3			
24. FAN INLET DPR, % OPEN	30	30			
25. OFFGAS ACCUM. PRESS, psig	3.6	3.6			
26.					
27. COMMENTS	REPEAT	TERT. AIR CLOSED			
28.	BASELINE	PRI - 60% OP			
29.		SEC. - 100% OP			
30. REFLUX TEMP, °F	110	110			

NG Flow :

Data Sheet 6002-1

UNIT OPERATING DATA

Test No._______

Test No. 1-13 to 1-17 Date 10-3-80 Location 1 Engr. Tidona

Unit No. F1 Fuel NG + Ref. Gas Capacity 14,000 bbl/d

Unit Type CRUDE HEATER (PETROCHEM) Burner Type Zink Lo-NOx DBA-PC-16

1. Test Number	1-13	1-14	1-15	1-16	1-17
2. Date	10-3-80	10-3-80	10-3-80	10-3-80	10-3-80
3. Time	09:16	09:26	09:52	10:22	11:14
4. Load					
5. Process Rate , bbl/d	11000	11040	11040	11040	11000
6 Crude to F1,Pass A,bbl/d	6160	6160	6160	6200	6160
7 Crude to F1,PassB,bbl/d	4840	4880	4880	4840	4840
8 Crude to F2 ([illegible]),bbl/d	1800	1770	1770	1830	1830
9. Offgas Flow	5.8	5.8	5.6	5.5	4.6
10 Crude in Temp,Pass A,°F	315	315	315	315	310
11 Crude in Temp,Pass B,°F	305	305	305	305	300
12 Crude Out Temp.A, °F	443	443	443	443	440
13 Crude Out Temp B, °F	437	435	435	437	434
14 Stack Temp, °F	430	412	398	450	385
15. Conv. Sect. Gas T in °F	795	790	780	780	735
16 Conv. Sect. Crude T Out, A, °F	360	350	350	365	345
17. Conv. Sect. Crude T Out, B, °F	348	341	340	358	340
18 Naptha Flow, bbl/d	1300	1350	1325	1300	1375
19. Crude Feed H_2O, %	1.2	1.2	1.2	1.2	0.4
20. Tower Press, psig	12.3	12.2	12.1	12.0	11.5
21 Crude in Press, B, psig	98	98	98	98	88
22. Natural Gas Flow, Scf	$53133.5^{09:20}$	$53036^{09:40}$	$53037^{09:57}$	$53041.5^{10:28}$	$53048.5^{11:21}$
23. Crude API Gravity	19.9	19.9	19.9	19.9	20.4
24. Fan Inlet Dpr , % Open	55	40	38	60	40
25. Offgas Accum Press., psig	6.5	6.5	6.5	6.5	6.5
26. Reflux Temp. , °F	118	115	115	115	110
27. Firebox/conv./stack P, in. H_2O	-.12/-.08/-.11	-.18/-.15/-.15	-.12/-.10/-.09	-.06/-.03/-.10	-.13/-.10/-.11
28. Primary Air Reg, % Open	60	60	60	60	60
29. Secondary Air Reg., % Open	100	100	100	100	100
30. Tertiary Air Reg., % Open	100	100	100	100	100
Comment	As Found 6% O_2	~4% O_2	CO limit Smoking a little	High O_2	Crude Tank Switch Baseline

Data Sheet 6002-1

NG Flow (Tests 1-13 to 1-16) = 5676 SCFH

NG Flow (Test 1-17) = 8214 SCFH

UNIT OPERATING DATA

Test No.________

Test No. 1-18 to 1-22 Date 10-3-80 Location 1 Engr. T. Lona

Unit No. F1 Fuel NG + Ref. Gas Capacity 14,000 bbl/d

Unit Type CRUDE HEATER Burner Type 3-NK Lo-NO_x DBA-PC-16

1. Test Number	1-18	1-19	1-20	1-21	1-22
2. Date	10-3-80	10-3-80	10-3-80	11-3-80	10-3-80
3. Time	11:51	12:14	12:38	12:56	13:19
4. Load					
5. Process Rate , bbl/d	11040	11000	11000	11000	11040
6 Crude to F1,Pass A,bbl/d	6160	6160	6160	6160	6200
7 Crude to F1,PassB,bbl/d	4880	4840	4840	4840	4840
8 Crude to F2([illegible]),bbl/d	1860	1860	1860	1860	1860
9. Offgas Flow	4.9	4.9	4.9	4.9	4.9
10 Crude in Temp,Pass A,°F	310	310	308	308	310
11 Crude in Temp,Pass B,°F	305	300	300	300	305
12 Crude Out Temp.A, °F	443	439	440	438	440
13 Crude Out Temp B, °F	436	435	435	433	430
14 Stack Temp, °F	385	390	385	385	385
15. Conv. Sect. Gas T in °F	730	730	740	725	735
16 Conv. Sect. Crude T Out, A, °F	345	345	345	343	350
17. Conv.Sect. Crude T Out, B, °F	335	335	340	335	340
18 Naptha Flow, bbl/d	1375	1375	1375	1375	1375
19. Crude Feed H_2O, %	0.4	0.4	0.4	0.4	0.4
20. Tower Press, psig	11.6	11.6	11.6	11.5	11.4
21 Crude in Press, B, psig	88	88	88	88	88
22. Natural Gas Flow, Scf	11:56 53053	12:21 53057	12:43 53059.5	12:59 53061.5	13:26 53065
23. Crude API Gravity	20.0	20.0	20.0	20.0	20.0
24. FAN INLET DPR, % OPEN	40	45	42	42	42
25. OFFGAS ACCUM PRESS, psig	6.5	6.5	6.5	6.5	6.5
26. REFLUX TEMP, °F	110	110	110	110	110
27. FIREBOX/CONV./STACK P, in. H_2O	-.16/-.12/-.12	-.17/-.13/-.15	-.18/-.15/-.15	-.18/-.15/-.15	-.17/-.13/-.13
28. PR./SEC./TERT. REG. % OPEN	0/100/100	100/0/100	50/50/100	0/50/100	60/100/100
29.					
30. COMMENT	ZERO PR. AIR	ZERO SEC. AIR	50% PR, 50% SEC	0% PR, 50% SEC	REPEAT BASELINE

NG Flow (Tests 1-18 to 1-22) = 8000 SCFH

Data Sheet 6002-1

UNIT OPERATING DATA

Test No._______

Test No. 1-23, 1-24 Date 10-3-80 Location 1 Engr. T:dona

Unit No. F1 Fuel NG + Ref Gas Capacity 14,000 bbl/d

Unit Type CRUDE HEATER Burner Type ZINK DBA-16 Lo-NOx

1. Test Number	1-23	1-24			
2. Date	10-3-80	10-3-80			
3. Time	13:45	14:12			
4. Load					
5. Process Rate , bbl/d	11040	11040			
6Crude to F1,Pass A,bbl/d	6200	6200			
7Crude to F1,PassB,bbl/d	4840	4840			
8Crude to F2([illegible]),bbl/d	1830	1830			
9. Offgas Flow	4.9	5.0			
10Crude in Temp,Pass A,°F	308	305			
11Crude in Temp,Pass B,°F	300	300			
12Crude Out Temp.A, °F	439	437			
13Crude Out Temp B, °F	429	432			
14Stack Temp, °F	385	370			
15. Conv. Sect. Gas T in °F	755	720			
16 Conv, Sect. Crude T Out, A, °F	345	340			
17. Conv. Sect. Crude T Out, B, °F	340	330			
18Naptha Flow, bbl/d	1350	1375			
19. Crude Feed H_2O, %	0.4	0.4			
20. Tower Press, psig	11.4	11.4			
21Crude in Press, B, psig	88	88			
22. Natural Gas Flow, Scf	53068 13:49	53071 14:16			
23. Crude API Gravity	20.0	20.0			
24. FAN INLET DPR, % OPEN	42	42			
25. OFFGAS ACCUM. PRESS, psig	6.5	6.5			
26. REFLUX TEMP. , °F	110	110			
27 FIREBOX, CONV., STACK P, in H_2O	-.17/-.13/-.13	-.21/-.19/-.18			
28. PR., SEC., TERT. REG., % OPEN	60/100/0	100/0/100			
29.					
30. COMMENT	ZERO TERT. AIR	ZERO SEC. AIR LOW O_2 lazy fire, smoky around edges			

Data Sheet 6002-1

NG Flow ≃ 7000 SCFH

TABLE 1. FUEL ANALYSES AT SITE 1.

Fuel Sample No. 1
Test 1-6
Sample Taken 10/2/80

Gaseous Species	Volume %
O_2	0.025
N_2	0.340
CH_4	8.93
CO_2	4.25
C_2H_6	6.09
C_3H_8	20.47
C_4H_{10}	31.63
C_5H_{12}	16.24
$\geq C_6$	11.87
CO	1000 ppm

HHV (Higher Heating Value) 107,500 kJ/m^3 (2,885 Btu/ft^3).

Natural Gas
Typical for all tests.

Gaseous Species	Volume %
Methane	88.09
Ethane	6.84
Propane	1.51
Isobutane	0.29
Nitrogen	1.47
Carbon Dioxide	1.73

HHV (Higher Heating Value) 38,861 kJ/m^3 (1,043 Btu/ft^3).

SITE 2

PETROLEUM PROCESS HEATER

Location No. SITE #2 Unit No. 1 H

Unit Description

VERTICAL CYLINDRICAL CRUDE PROCESS HEATER

Installation Date N/A

Heater Rating 33,12 m^3/H

Burner Description ONE (1) JOHN ZINK LOW NOX BURNER LNC-16

Test Fuel Combinations NUMBER #2 DISTILLATE OIL

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) AMBIENT

Comments:

MOBILE LABORATORY DATA

Test No.________

Test No. 9/1, 9/4, 9/2 Date 10/22/80 Location__________ Engr. J Hart

Unit No.________ Fuel________ Capacity________

Unit Type________ Burner Type________

Base Line ↓

1. Test No.	8/1-1E		8/1-1F		9/1-1G		9/2-1A		9/2-1B	
2. Date 10/22/80	2		2		2		2		2	
3. Time	0930		0945		1000		1015		1030	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position center										
8. Oxygen (%)	5.1%		6.6		8.1		4.5		5.7	
9. NOx (hot) read/3% O_2 (ppm)*	122		139		126		134		133	
10. NO (hot) read/3% O_2 (ppm)*	117		132		125		131		131	
11. NO_2 (hot) read/3% O_2 (ppm)*	5		2		1		3		2	
✓12. NO (cold) read/3% O_2 (ppm)*	149	168	157	196	152	212	151	165	162	191
13. Carbon Dioxide (%)	11.4		9.0		8.0		11.8		11.4	
✓14. Carbon Monoxide (ppm) uncor/cor*	10	11	10	13	0		10	11	10	12
15. Hydrocarbon (ppm) uncor/cor*	-	-	10		5		10		5	
16. Sulfur Dioxide (ppm) uncor/cor*	290		235		200		345		290	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	65		65		68		70		70	
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.04		30.04		30.04		30.09		30.04	
21. Relative Humidity (%)	57%		57%				53%		53%	
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. 9/3-1

Test No. 9/3, 9/4 Date 10/22/80 Location ________ Engr. J. Hart

Unit No. ________ Fuel Diesel Capacity ________

Unit Type ________ Burner Type ________

	2		2		2		2		2	
1. Test No. 9/3-1	9/3-1A		9/3-1B		9/4-1A		9/4-1B		9/3-1C	
2. Date 10/22/80										
3. Time	1100		1115		1130		1150		1210	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position center										
8. Oxygen (%)	3.6		5.8		4.8		3.7		3.6	
9. NOx (hot) read/3% O_2 (ppm)*	111		128		129		123		114	
10. NO (hot) read/3% O_2 (ppm)*	107		126		126		121		107	
11. NO_2 (hot) read/3% O_2 (ppm)*	4		2		3		2		7	
✓ 12. NO (cold) read/3% O_2 (ppm)*	120	124	155	184	160	178	157	163	125	129
13. Carbon Dioxide (%)	12.2		10.2		11.0		12.0		12.2	
✓ 14. Carbon Monoxide (ppm) uncor/cor*	540	559	10	12	10	11	30	31	100	103
15. Hydrocarbon (ppm) uncor/cor*	5		0		0		0		0	
16. Sulfur Dioxide (ppm) uncor/cor*	445		300		350		370		440	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	70		70		73°F		73°F		76	
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.04		30.04		30.04		30.04		30.04	
21. Relative Humidity (%)	53%		53%		48%		48%		47%	
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.________

Test No.________ Date 10/23/80 Location____________ Engr. J. Hart

Unit No.________ Fuel________ Capacity____________

Unit Type____________ Burner Type____________

	2		2		2		2		2	
1. Test No.	9/1-3A		9/1-3B		9/8-1A		9/8-1B		9/8-1C	
2. Date 10/23/80										
3. Time	1000		1015		1040		1050		1110	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position center										
8. Oxygen (%)	4.0		4.1		3.1		2.8		4.1	
9. NOx (hot) read/3% O_2 (ppm)*			116		86		86		116	
10. NO (hot) read/3% O_2 (ppm)*			113		81		82		113	
11. NO_2 (hot) read/3% O_2 (ppm)*			3		5		4		3	
12. NO (cold) read/3% O_2 (ppm)*	137	145	132	141	104	105	102	101	138	147
13. Carbon Dioxide (%)	11.6		11.8		12.8		13.2		12.0	
14. Carbon Monoxide (ppm) uncor/cor*	10	11	10	11	90	40	240	237	20	21
15. Hydrocarbon (ppm) uncor/cor*	10		0		0		0		0	
16. Sulfur Dioxide (ppm) uncor/cor*	270		360		400		420		390	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	69°F		69°		73°F		74°F		74°F	
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.11		30.11		30.11		30.12		30.12	
21. Relative Humidity (%)	51%		51%		49.%		46%		46%	
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.________

Test No.________ Date 10/23/80 Location________ Engr. J. Hart

Unit No.________ Fuel________ Capacity________

Unit Type________ Burner Type________

1. Test No.	2									
2. Date 10/23/80	91-48									
3. Time	1115									
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	4.2									
9. NOx (hot) read/3% O_2 (ppm)*	116									
10. NO (hot) read/3% O_2 (ppm)*	115									
11. NO_2 (hot) read/3% O_2 (ppm)*	1									
12. NO (cold) read/3% O_2 (ppm)*	142	152								
13. Carbon Dioxide (%)	12.0									
14. Carbon Monoxide (ppm) uncor/cor*	10	11								
15. Hydrocarbon (ppm) uncor/cor*	10									
16. Sulfur Dioxide (ppm) uncor/cor*	380									
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	74°									
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.12									
21. Relative Humidity (%)	46%									
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA **Test No.**_______

Test No. 9/1-9/2 **Date** 10-22-80 **Location** 2 **Engr.** HART, GEBE

Unit No. H 1 **Fuel** diesel oil **Capacity** 5000 bbl/d 10 M BTU/H

Unit Type crude heater **Burner Type** Zink DB-82-16R

	baseline	baseline	baseline	primary air adjustment	primary
1. Test Number	9/1-1e	9/1-1f	9/1-1g	9/2-1a	9/2-1b
2. Date	10-22-80	10-22-80	10-22-80	10-22-80	10-22-80
3. Time	930	945	1000	1015	1030
4. Load bbl/d	5000	5000	5000	5000	5000
5. ~~Process Rate~~					
6. T crude out Ckt °F	(285)2	(275)2	(270)2	(284)2	(290)2
7. " " " gauge "	642	628	609	639	649
8. P crude out psig	32	32	31	33	32
9. P crude in psig	145	142	140	142	138
10. Stack T °F	1100-1160				
11.					
12. Flame Obs.	ok				
13.					
14. Port. O2	4.6-6.3				
15.					
16. Atm Steam P psig	96	103	105	112	112
17. Fuel P psig	143	143	143	141	142
18.					
19. Primary % open	100%	100	100	50	50
20. Secondary % open	100%	100	100	100	100
21. Tertiary % open	100%	100	100	100	100
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

UNIT OPERATING DATA

Test No.______

Test No.______ Date 10/23/80 Location ~~8~~ 2. Engr. HARTGABE

Unit No. 1H Fuel diesel oil Capacity 5000 bbl /d

Unit Type Crude heater Burner Type Zink DB-92-16A

	baseline	baseline			
1. Test Number	9/1-3a	9/1-3b	9/8-1a	9/8-1b	9/8-1c
2. Date	2 10-23	2 11-23	2 10-23	2 10-23	2 10-23
3. Time	1000	1015	1040	1050	1055
4. Load	5000	5000	5000	5000	5000
5. Process Rate					
6. T crude out chart	(292)2	(285)2	(290)2	(291)2	(292)2
7. gauge	634	639	646	~~7~~ 650	650
8. P crude out	30	30	31	31	31
9. P crude in	132	132	132	132	132
10. Stack T	1140				1050
11.					
12. Flame					
13.					
14. Port. O_2					
15.					
16. Atm Steam P	112	116	116	116	116
17. Fuel P	146	146	146	146	146
18.					
19. Primary	100	100	50	50	50
20. Secondary	100	100	70	70	70
21. Tertiary	100	100	100	100	100
22.					
23. Obs			close		
24.			to smoke		
25.			limit		
26.					
27.					
28.					
29.					
30.					

partially through bypass, so must add correction of 5 or 10%

Data Sheet 6002-1

17238 gal 400 AM 10-23-80	16906 gal 10-22-80	16487 gal 10-21-80

UNIT OPERATING DATA

Test No.________

Test No.________ Date 10-23-80 Location A 2 Engr. HART, GABE

Unit No. 1H Fuel diesel oil Capacity 5000 bbl/d

Unit Type crude heater Burner Type Zink DB-82-16A

	2	2			
1. Test Number	A/1-4a	A/1-4b			
2. Date	10-23	10-23			
3. Time	1110	1115			
4. Load	5000	5000			
5. Process Rate					
6. T crude out chart	(300)2	(298)2			
7. gauge	644	643			
8. P crude out	~~7~~30	30			
9. P crude in	132	131			
10. Stack T					
11.					
12. Flame					
13.					
14. Port. O_2					
15.					
16. Atm. Steam P	112	112			
17. Fuel P	146	146			
18.					
19. Primary	100	100			
20. Secondary	100	100			
21. Tertiary	100	100			
22.					
23. Obs					
24.					
25.					
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

FUEL ANALYSIS, OIL FUEL, TEST SITE 2

Ultimate Analysis:	
Carbon, %	85.74
Hydrogen, %	12.02
Nitrogen, %	0.15
Sulfur, %	0.69
Ash, %	0.003
Oxygen, % (by difference)	1.40
Heat of Combustion:	
Gross Btu/lb	19,000
Net Btu/lb	17,900

SITE 3

PETROLEUM PROCESS HEATER

Location No. SITE #3 Unit No. #1

Unit Description

HORIZONTAL NATURAL DRAFT PROCESS HEATER

Installation Date N/A

Heater Rating 106.0 M^3/H

Burner Description TWELVE (12) JOHN ZINK LOW NOX LNC-12

Test Fuel Combinations NUMBER #6 OIL

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) AMBIENT

Comments:

MOBILE LABORATORY DATA

Test No.________

Test No.________ Date 10-28-80 Location________ Engr. K.

Unit No. 1 Fuel #6 Capacity 16 000 BPD

Unit Type Horiz. Heater Burner Type John Zink DR-82-14A

1. Test No.	3-1		3-2		3·3		3-4			
2. Date 10/28/80										
3. Time	10:35		1150		1355		1510			
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position center	℄									
8. Oxygen (%)	5.2		4.6		4.3		5.3			
9. NOx (hot) read/3% O_2 (ppm)*	311	–	318		282		291	-		
10. NO (hot) read/3% O_2 (ppm)*	310	–	315		280		289	-		
11. NO_2 (hot) read/3% O_2 (ppm)*	1	–	1		2		2	-		
12. NO (cold) read/3% O_2 (ppm)*	348	396	365	401	335	361	336	385		
13. Carbon Dioxide (%)	10.1		11.5		11.1		10.3			
14. Carbon Monoxide (ppm) uncor/cor*	10	11	10	11	10	11	10	11		
15. Hydrocarbon (ppm) uncor/cor*	10	–	0		0		0	-		
16. Sulfur Dioxide (ppm) uncor/cor*	758	–	530		340		560	-		
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	74°F		75°F		78°F					
19. Dew Point Temp. (°F/°C)					Register adjustment and lower O_2					
20. Atmos. Pressure (in. Hg)	30.32		30.32							
21. Relative Humidity (%)	26%		26%		36%					
22.										
23.			As found				Flame adjustment			
24.	As found									
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.________

Test No.________ Date 10-29-80 Location

Engr. Ks.

Unit No. 1 Fuel #6 oil Capacity 16 000 BPD

Unit Type Horiz. Heater Burner Type John Zink DB-82-14A

1. Test No.	3-5		3-6				
2. Date	10-29-80		→		→	→	→
3. Time	1020		1100				
4. Load							
5. Process Rate							
6. Flue Diam. or Size, ft							
7. Probe Position	℄						
8. Oxygen (%)	5.2		5.3				
9. NOx (hot) read/3% O_2 (ppm)*	281	-	288				
10. NO (hot) read/3% O_2 (ppm)*	276	-	288				
11. NO_2 (hot) read/3% O_2 (ppm)*	5	-	0	-			
12. NO (cold) read/3% O_2 (ppm)*	324	369	329	377			
13. Carbon Dioxide (%)	10.6		11.4				
14. Carbon Monoxide (ppm) uncor/cor*	10	11	10	11			
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-			
16. Sulfur Dioxide (ppm) uncor/cor*	425	-	430	-			
17. Smoke Spot (Bacharach)							
18. Atmos. Temp. (°F/°C)	74						
19. Dew Point Temp. (°F/°C)	59						
20. Atmos. Pressure (in. Hg)							
21. Relative Humidity (%)	42						
22.							
23.							
24.							
25.	Register adjustment		Register adjustment				
26.							
27.							
28.							
29.							
30.							

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA

Test No. 3-1

Test No. 3-1 **Date** 10-28-80 **Location** SITE 3 **Engr.** H.B

Unit No. #1 **Fuel** NO #6 OIL **Capacity**

Unit Type HORIZONTAL DRAFT HEATER **Burner Type** JOHN ZINK LNC-12

1.Test Number	3-1				
2.Date	10-28-80				
3.Time	10:35				
4.Load					
5.Process Rate	106.0 M3/H				
6.West Flow (BPH)	6.1				
7.East Flow (BPH)	6.1				
8.Product Temp °F East	665				
9.Product Temp °F West	660				
10.Stack Temp °F	1170				
11.Stack Damper (% OPEN)	90				
12.					
13.COMMENTS: #1 BURNER	OUT DUE	TO HIGH	PRODUCT OUT	LET TEMP	ON WEST SIDE
14.Burner OOS #1					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	0	60	70	70	100	100	90	90	110	90	80	100
Sec Regist	0	70	70	70	90	100	90	90	100	90	90	100
Tert "(% Open)	0	70	70	90	80	70	100	60	80	90	90	100
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 3-2

Test No. 3-2 Date 10-28-80 Location SITE 3 Engr. H.B.

Unit No. #1 Fuel #6 OIL Capacity

Unit Type HORIZONTAL DRAFT HEATER Burner Type JOHN ZINK LNC-12

1.Test Number	3-2				
2.Date	10-28-80				
3.Time	11:50				
4.Load					
5.Process Rate	106.0 M^3/H				
6.West Flow (BPH) x 46.2	6.1				
7.East Flow (BPH) x 46.2	6.0				
8.Product Temp °F East	655				
9.Product Temp °F West	660				
10.Stack Temp °F	1170				
11.Stack Damper	90				
12.					
13.COMMENTS: TUBES IN CONVECTION SECTION ARE DIRTY NORMAL TEMP 1000 °F					
14.Burner OOS #1					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	OOS	60	70	70	100	100	40	90	100	80	80	100
Sec Regist	0	70	70	70	90	100	90	90	100	90	80	100
Tert "(% Open)	0	70	70	90	80	70	100	60	80	90	70	100
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 3-3

Test No. 3-3 **Date** 10-28-80 **Location** SITE 3 **Engr.** HB

Unit No. #1 **Fuel** #6 OIL **Capacity**

Unit Type HORIZ DRAFT HEATER **Burner Type** JOHN ZINK LNC-12

1. Test Number	3-3				
2. Date	10-28-80				
3. Time	13:55				
4. Load					
5. Process Rate	106.0 M³/H				
6. West Flow (BPH) Y 46.2	6.1				
7. East Flow (BPH) Y46.2	6.1				
8. Product Temp °F East	665				
9. Product Temp °F West	662				
10. Stack Temp °F	1200				
11. Stack Damper	90% OPEN				
12.					
13. COMMENTS: #2 BURNER WAS	REMOVED AT	13:00 DUE	TO HIGH PRODUCT TEMP.		STACK DAMPER IS
14 Burner OOS #1 & #7	CLOSED				STUCK

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	OOS	60	70	80	50	50	Closed	60	50	50	50	50
Sec Regist	0	70	70	70	60	60		70	70	70	50	60
Tert "(% Open)	0	70	70	60	80	80	OOS	70	70	70	70	50
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

*** O.O.S. - OUT OF SERVICE**

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 3-4

Test No. 3-4 Date 10-28-80 Location SITE # 3 Engr. H.B.

Unit No. #1 Fuel #6 OIL Capacity

Unit Type HORIZ DRAFT HEATER Burner Type JOHN ZINK LNC-12

1.Test Number	3-4				
2.Date	10-28-80				
3.Time	15:10				
4.Load					
5.Process Rate	106.0 M³/H				
6.West Flow (BPH) X46.2	660				
7.East Flow (BPH) "	660				
8.Product Temp °F East	6.1				
9.Product Temp °F West	6.1				
10.Stack Temp °F	1200				
11.Stack Damper	90% OPEN				
12.					
13.COMMENTS: #5 & #11 BURNER WERE ADJ. IMPINGMENT WAS ELIMINATED					
14.Burner OOS #1 & #7					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	OOS	60	70	80	50	50	OOS	60	50	50	50	50
Sec Regist	OOS	70	70	70	60	60	OOS	70	70	70	50	60
Tert "(% Open)	OOS	70	70	60	80	80	OOS	70	70	70	70	50
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

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Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 3-5

Test No. 3-5 **Date** 10-29-80 **Location** SITE #3 **Engr.** H.B

Unit No. #1 **Fuel** #6 OIL **Capacity**

Unit Type HORIZ DRAFT HEATER **Burner Type** JOHN ZINK LWC-12

1. Test Number	3-5				
2. Date	10-29-80				
3. Time	10:20				
4. Load					
5. Process Rate	106.0 M³/H				
6. West Flow (BPH) V4/6.2	6.1				
7. East Flow (BPH) "	6.1				
8. Product Temp °F East	645				
9. Product Temp °F West	650				
10. Stack Temp °F	1160				
11. Stack Damper	90% OPEN				
12.					
13. COMMENTS: REGISTER ADJ.					
14. Burner OOS #1 & #7					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	CLOSED	60	70	60	50	50	CLOSED	50	50	50	50	50
Sec Regist		60	60	60	60	60		60	60	50	60	50
Tert "(% Open)		80	70	60	80	80		60	70	50	60	50
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 3-6

Test No. 3-6 Date 10-29-80 Location SITE #3 Engr. H.B

Unit No. #1 Fuel #6 OIL Capacity

Unit Type HORIZ DRAFT HEATER Burner Type JOHN ZINK LNK-12

1.Test Number	3-6				
2.Date	10-29-80				
3.Time	11:05				
4.Load					
5.Process Rate	106.0 M^3/H				
6.West Flow (BPH) Y46.2	6.1				
7.East Flow (BPH) Y46.2	6.1				
8.Product Temp °F East	650				
9.Product Temp °F West	655				
10.Stack Temp °F	1160				
11.Stack Damper	90% OPEN				
12.					
13.COMMENTS: REGISTER ADJ					
14.Burner OOS #1 & #7					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	CLOSED	60	70	60	50	50	CLOSED	50	50	50	50	50
Sec Regist		60	60	60	60	60		60	60	50	60	50
Tert "(% Open)		80	70	60	80	80		60	70	50	60	50
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

FUEL ANALYSIS, OIL FUEL, TEST SITE 3

Ultimate Analysis:	
Carbon, %	85.87
Hydrogen, %	11.13
Nitrogen, %	0.81
Sulfur, %	1.11
Ash, %	0.027
Oxygen, % (by difference)	1.05
Heat of Combustion:	
Gross Btu/lb	18,530
Net Btu/lb	17,520
API Gravity @ 60°F	12.7

SITE 4

PETROLEUM PROCESS HEATER

Location No. SITE #4 **Unit No.** #2

Unit Description

VERTICAL CYLINDRICAL NATURAL DRAFT PROCESS HEATER

Installation Date N/A

Heater Rating ~~3.756 M^3/H~~ 99 m^3/h

Burner Description THREE (3) JOHN ZINK LNC-16 LOW NOX BURNERS

Test Fuel Combinations NO. #6 OIL

Fuel Temp. at Burner (°F) APPX 180°F

Primary Air Temp. (°F) AMBIENT

Comments:

MOBILE LABORATORY DATA **Test No.**

Test No. **Date** 10·29·80 **Location** **Engr.** B.

Unit No. 2 **Fuel** #6 **Capacity** 16 000 BPD

Unit Type Vert Heater **Burner Type** John Zink DB82-16A

1. Test No.	4-1									
2. Date	10·29·80									
3. Time	15:40									
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	℄									
8. Oxygen (%)	8.1									
9. NOx (hot) read/3% O_2 (ppm)*	297	-								
10. NO (hot) read/3% O_2 (ppm)*	294	-								
11. NO_2 (hot) read/3% O_2 (ppm)*	3	-								
12. NO (cold) read/3% O_2 (ppm)*	342	477								
13. Carbon Dioxide (%)	7.4%									
14. Carbon Monoxide (ppm) uncor/cor*	0	0								
15. Hydrocarbon (ppm) uncor/cor*	0	-								
16. Sulfur Dioxide (ppm) uncor/cor*	425	-								
17. Smoke Spot (Bacharach)	-									
18. Atmos. Temp. (°F/°C)	78°F									
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.30									
21. Relative Humidity (%)	36%									
22.										
23.										
24.										
25.	As Found									
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.

Test No. Date 10-30-80 Location , Engr. K.

Unit No. 2 Fuel #6 Capacity 16 000 BPD

Unit Type Vert. Heater Burner Type John Zink DB 82-16A

1. Test No.	4-2		4-3		4-4		4-5		4-6	
2. Date 10/30/80										
3. Time	0940		1017		1130		1430		1500	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	11.4		7.6%		7.1		7.8		6.9	
9. NOx (hot) read/3% O_2 (ppm)*	243	-	296		312	-	318		313	
10. NO (hot) read/3% O_2 (ppm)*	235	-	294		310	-	318		311	
11. NO_2 (hot) read/3% O_2 (ppm)*	8		2		2	-	0		2	
12. NO (cold) read/3% O_2 (ppm)*	270	506	347	466	364	471	370	504	375	478
13. Carbon Dioxide (%)	6.2%		9.2%		8.6		9.7		10.2	
14. Carbon Monoxide (ppm) uncor/cor*	10	19	10	13	0	0	0	0	10	13
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-	0	-	0		0	
16. Sulfur Dioxide (ppm) uncor/cor*	410		455		440	-	340	-	370	
17. Smoke Spot (Bacharach)	-									
18. Atmos. Temp. (°F/°C)	72°F		72°F		72°F		80°F		80°F	
19. Dew Point Temp. (°F/°C)										
20. Atmos. Pressure (in. Hg)	30.25		30.25		30.25		30.19		30.19	
21. Relative Humidity (%)	44%		44%		44%		31%		31%	
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA **Test No.**________

Test No.________ **Date** 11-4-80 **Location**________ **Engr.** H. Buening

Unit No. 2 **Fuel** #6 **Capacity** 16 000 BPD

Unit Type Vert. Heater **Burner Type** John Zink DB 82-16A

1. Test No.	4-7		4-8							
2. Date 11-4-80										
3. Time	1005		1015							
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	11.5%		8.8%							
9. NOx (hot) read/3% O_2 (ppm)*	235		239							
10. NO (hot) read/3% O_2 (ppm)*	233		237							
11. NO_2 (hot) read/3% O_2 (ppm)*	2		2							
12. NO (cold) read/3% O_2 (ppm)*	262	496	263	388						
13. Carbon Dioxide (%)	5.6%		7.4%							
14. Carbon Monoxide (ppm) uncor/cor*	0	-	0							
15. Hydrocarbon (ppm) uncor/cor*	0		0							
16. Sulfur Dioxide (ppm) uncor/cor*	310		420							
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	76		75							
19. Dew Point Temp. (°F/°C)	61		61							
20. Atmos. Pressure (in. Hg)	30.23		30.23							
21. Relative Humidity (%)	48		43							
22.										
23.	Partial Test									
24.			:							
25.										
26.			:							
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA

Test No. 4-1

Test No. 4-1 **Date** 10-29-80 **Location** SITE #4 **Engr.** H.B

Unit No. # 2 **Fuel** #6 OIL **Capacity** 16000 BPD

Unit Type VERT. HEATER **Burner Type** JOHN ZINK ZNC-16

1.Test Number	4-1				
2.Date	10-29-80				
3.Time	15:40				
4.Load					
5.Process Rate	3.756 M³/H				
6.~~West~~ NORTH Flow (BPH) X 42.6	6.6				
7.~~East~~ SOUTH Flow (BPH) X 42.6	6.7				
8.Product Temp °F ~~East~~ NORTH	704				
9.Product Temp °F ~~West~~ SOUTH	700				
10. Stack Temp °F	860 °F				
11. Stack Damper	100 % OPEN				
12.					
13.COMMENTS: AS FOUND					
14. Burner OOS					

Burner No.	NORTH 1	WEST 2	EAST 3	4	5	6	7	8	9	10	11	12
Prim Regist	80	80	100									
Sec Regist	80	100	80									
Tert "(% Open)	90	100	70									
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

Test No. 4-2/4-3/4-4/4-5

UNIT OPERATING DATA

Test No. 4-2/4-3/4-4/4-5 Date 10-30-80 Location SITE # 4 Engr. H.B

Unit No. # 2 Fuel #6 OIL Capacity 16000 BPD

Unit Type VERT. HEATER Burner Type JOHN ZINK LNC-16

1.Test Number	4-2	4-3	4-4	4-5	
2.Date	10-30-80	10-30-80	10-30-80	10-30-80	
3.Time	0945	10:17	11:30	14:30	
4.Load					
5.Process Rate					
6.~~West~~ NORTH Flow (BPH) x42.6	6.5	6.5	6.6	6.5	
7.~~East~~ SOUTH Flow (BPH) x42.6	6.8	6.9	6.7	6.7	
8.Product Temp °F ~~East~~ NORTH	695	705	698	700	
9.Product Temp °F ~~West~~ SOUTH	695	700	694	695	
10.Stack Temp °F	790	895	880	900	
11.Stack Damper BOTH DAM-	PERS WIDE OPEN	1 DAMPER 100% OTHER 20%	SOUTH 100% OPEN NORTH 20% "	→	
12.					
13.COMMENTS: STACK DAMPER	ADJ. →		REGISTER ADJ.	REGISTER ADJ.	
14.Burner OOS					

	4-2				4-3		4-4					
Burner No.	NORTH 1	WEST 2	EAST 3	NORTH 4	WEST 5	EAST 6	NORTH 7	WEST 8	EAST 9	NORTH 10	WEST 11	EAST 12
Prim Regist	80	70	100	80	70	100	60	60	60	60	60	60
Sec Regist	90	100	80	80	100	80	60	70	70	60	70	70
Tert *(% Open)	90	100	90	90	100	70	90	80	90	90	80	80
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27. COMMENTS.	TEST 4-3	1 DAMPER	80%	(NORTH) CLOSED								
28. COMMENTS:	4-4	AFTER	REGIST.	ADJ.	FUEL	GUNS	CUTBACK	ON EAST	BURNER	PRODUCT	TEMP	700 °F
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. #4-6

Test No. 4-6 Date 10-30-80 Location SITE #4 Engr. H.B.

Unit No. #2 Fuel #6 OIL Capacity 16000 BPD

Unit Type VERT. HEATER Burner Type JOHN ZINK LNC-16

1.Test Number	4-6				
2.Date	10-30-80				
3.Time	15:00				
4.Load					
5.Process Rate					
6.~~West~~ NORTH Flow (BPH) √42.6	6.3				
7.~~East~~ SOUTH Flow (BPH) √42.6	6.7				
8.Product Temp °F East	707				
9.Product Temp °F West	700				
10.Stack Temp °F	885				
11.Stack Damper	REGISTER ADJ.				
12.					
13.COMMENTS: SAME AS TEST @ 11:30					
14.Burner OOS					

Burner No.	NORTH 1	WEST 2	EAST 3	4	5	6	7	8	9	10	11	12
Prim Regist	50	50	50									
Sec Regist	50	50	60									
Tert *(% Open)	80	70	70									
20.												
21.												
22.												
23.												
24.												
25.												
26.												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 4-7/4-8

Test No. 4-7/4-8 **Date** 11-4-80 **Location** SITE #4 **Engr.** H.B

Unit No. #2 **Fuel** #6 OIL **Capacity** 16000 BPD

Unit Type VERT. HEATER **Burner Type** JOHN ZINK LPIC-16

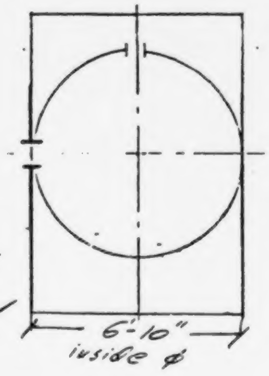
1.Test Number	4-7				
2.Date	11-4-80				
3.Time					
4.Load					
5.Process Rate					
6 ~~West~~ NORTH Flow (BPH) X 42.6	6.8				
7.~~East~~ SOUTH Flow (BPH) X 42.6	7.4				
8.Product Temp °F ~~East~~ NORTH	695				
9.Product Temp °F ~~West~~ SOUTH	695				
10.Stack Temp °F	822				
11.Stack Damper	NORTH 20% OPEN SOUTH 100% "				
12.					
13.COMMENTS: PARTICULATE	TEST				
14.Burner OOS					

Burner No.	NORTH 1	WEST 2	EAST 3	4	5	6	7	8	9	10	11	12
Prim Regist	50	50	50									
Sec Regist	60	60	60									
Tert "(% Open)	80	80	80									
20.												
21.												
22.												
23.												
24.												
25.												
26. COMMENTS:	HEATER	COND	ARE	THE	SAME	FOR	TEST	4-7	AND	4-8		
27.	PLANT	RESET	SEC RESIST	TO	60%	OPEN						
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

SMOKESTACK FLOW PROFILE



T NO.

LOCATION NO.

DATE 11-4-80

SAMPLING LOCATION stack

INSIDE OF FAR WALL TO

OUTSIDE OF NIPPLE, (DISTANCE A) ______ BAROMETRIC PRESS, in.Hg 29.92

INSIDE OF NEAR WALL TO

OUTSIDE OF NIPPLE, (DISTANCE B) ______ STACK PRESS., Ps, iwg -.15 ✓

STACK I.D. (DISTANCE A - DISTANCE B) ____ STK. GAS SP. GRAVITY, G_S 1.0

NEAREST UPSTREAM DISTURBANCE

NEAREST DOWNSTREAM DISTURBANCE

TRAVERSE POINT NUMBER	% OF STACK DIAMETER	DISTANCE FROM INSIDE WALL	VELOCITY HEAD (Δp_s), in. H_s0	STACK TEMPERATURE (T_s, °F	OXYGEN %	STACK GAS SPEED, Vs ft/min
1.	4.4	3½"	.01	860		
2.	14.7	12"	.01			
3.	29.5	24"	.01			
4.	70.5	58"	.01			
5.	85.3	70"	.01			
. ✓	95.6	78"	.01			
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
Average						

STACK GAS SPEED, $$V_s = 174\ F_s \sqrt{\overset{\text{Average}}{\Delta P}(T_s + 460)\ (\frac{407}{P_s})\ (\frac{1.00}{G_s})}$$

KVB

Test No. 4-7

Engr. Ko.

STACK DATA

Date 11-4-80 Location ______ Unit No. 2 Fuel #6

Load ______ K#/hr or MBtu/hr ______ Filter No. A

Sample Box No. ______ Meter Box No. CU-3 073704 Probe No. ______ Probe Length ______

Stack Moisture 8 estim.%

Ambient Temperature 76 °F

Nozzle Diameter 1/2 in.

Atmospheric Pressure 29.92 in.Hg

Stack Gas Pressure, Ps -.15" iwg

Stack Area, As 36.67 ft^2

Remarks:

Final Meter: 2078.71

Initial Meter: 2047.62

Time	Vm (CF)	Vacuum (in. Hg)	ΔP (iwg)	ΔH (iwg)	T_s (°F)	$T_{imp.in}$ (°F)	$T_{imp.out}$ (°F)	T_{filter} (°F)	in / out T_m (°F)
1307 1)	2052.63	2	.01	.28	860	69	133	255	86 / 82
2)	2057.49	2	.01	.28		69	168	280	87 / 84
3)	2062.52	2	.01	.28		72	178	290	90 / 88
4)	2068.70	2	.01	.28		66	181	288	91 / 88
5)	2073.80	2	.01	.28		66	184	286	93 / 87
6)	2078.71	2	.01	.28		67	188	286	93 / 88
NOTE:	17 min	Points							
TOTAL									
AVER.			.01	.28	860				90 / 86

Rev. 5/79

A Research-Cottrell Company

PARTICULATE CALCULATION SHEET

Test No. 1 (Inlet, Outlet)
Box No. ____
Test Description: Baseline

Location ____
Test Date 11.4.80

Dry Gas Meter Vol (ft3)
Final 2078.71
Initial 2047.62
Total 31.09

Impinger Water Vol (ml)

	1	2	3	Total	
Final	200	56	1	207	
Initial	100	100	0	200	
△ Vol	100	-44	1	7	64

	Impinger (Water)	Probe (Acetone)	Probe (Water)	Cyclone (Acetone)	Flask (Dry)	Filter No.	Blank No.
Beaker No.		2				A	
Date Weighed							
Tare Wt. 1		99.5044					
2		99.5045					
3		99.5044					
4							
5							
6							
Avg		99.5044				0.7658	
Bottle No.							
Rinse (ml)		300					
.te Weighed or 250 Bake)							
Final Wt. 250 1		99.5401				0.8602	
2		99.5400				0.8606	
3		99.5402				0.8606	
4							
5							
6							
Avg		99.5401				0.8605	
Residue Wt Final 250 Tare)		0.0357				0.0947	
Date Weighed or 650 Bake)							
Final Wt. 650 1							
2							
3							
4							
5							
6							
Avg							
Residue Wt. Final 650 Tare)							

Comments: Acetone Blank
.0014/200 ml

.0357
+.0947
.1304
-.0032
.1272

8830-5

HP-67 KEYED CALCULATION SHEET*

PARTICULATE EMISSION CALCULATIONS

Test No. 1 Date 11-4-80 Location ______ Engr. K.

Unit No. 2 Fuel #6 Sampling Train and Method 5

Pitot Factor, Fs .83 Barometric Pressure, P_{bar} 29.92 (STO 0) in. Hg

Tot. Liquid Collected, V_{1c} 64 ✓ (STO 1) ml Total Particulate, M_n 127.2 ✓ (STO 2) mgm

Velocity Head, ΔP .01 ✓ (STO 3) iwg Stack Temp., Ts 860 ✓ (STO 4) °F Stack Area, As 36.67 ✓ (STO 5) ft^2

Sample Volume, Vm 31.09 ✓ (STO 6) ft^3 Stack Press., Psg -.15 ✓ (STO 7) iwg Excess O_2, XO_2% 10.2 ✓ (STO 8) %

Orifice Press. Diff., H .28 ✓ (STO 9) iwg Stack Gas Sp. Gravity, Gs 1.0 (STO A) n.d.

Sample Time, θ 102 ✓ (STO B) min Nozzle Dia., Dn 0.50 ✓ (STO C) in. Meter Temp., T_m 88 ✓ (STO D) °F

Select Fe	Oil (A) ✓	Gas (B)	Coal (C)	Other:
SC Feet/10^4 Btu	92.2	87.4	98.2	(□)

Press (E) if meter is not temperature compensated.

1. Sample Gas Volume $Vm_{std} = 0.0334\ Vm(P_{bar} + H/13.6)$ 30.07 SCF
2. Water Vapor $Vw_{std} = 0.0474\ V_{1c}$ 3.03 SCF
3. Moisture Content Bwo = Eq. 2/(Eq. 1 + Eq. 2) 0.092 N.D.
4. Concentration a. $C = 0.0154\ Mn/Vm_{std}$ .065 grains/DSCF
   b. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$ .00001 lb/DSCF
   c. $C = \text{Eq. 4b} \times 16.018 \times 10^3$ .1494 grams/DSCM
5. Abs. Stack Press. $Ps = P_{bar} \times 13.6 + Psg$ 406.8 in. w abs.
6. Stack Gas Speed $Vs = 174\ Fs \sqrt{\Delta PTs} \sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$ 524.9 ft/min
7. Stack Gas Flow Rate @ 70°F a. $Qsw = \text{Eq. 6} \times As \times \frac{530}{Ts} \times \frac{Ps}{407}$ 7722 WSCF/min
   b. Qsd = Eq. 7a x (1. - Eq. 3) 7014 DSCF/min
8. Material Flow Ms = Eq. 7b x Eq. 4b x 60 3.93 lb/hr
9. XO_2 factor $XO_2f = 2090/(20.9 - XO_2\%)$ 195.33 N.D.
10. Emission a. E = Eq. 4b x Fe x Eq. 9 .1680 lb/MMBtu
    b. E = Eq. 4c x Fm x Eq. 9 x 1000 72.24 ng/joule
11. % Isokinetic $I = \frac{14077 \times Ts(Vm_{std} + Vw_{std})}{\theta \times Vs \times Ps \times Dn^2}$ 112.98 %

*If calculating by hand:
1) Convert T_S and T_m to °R
2) Multiply EQ 1 by $530/T_m$(°R) if meter not temperature compensated.
3) $F_m = 2.684 \times 10^{-5} \times Fe$

Data Sheet 6002-4
Revised 2/15/78

FUEL ANALYSIS, OIL FUEL, TEST SITE 4

Ultimate Analysis:	
Carbon, %	85.87
Hydrogen, %	11.13
Nitrogen, %	0.81
Sulfur, %	1.11
Ash, %	0.027
Oxygen, % (by difference)	1.05
Heat of Combustion:	
Gross Btu/lb	18,530
Net Btu/lb	17,520
API Gravity @ 60°F	12.7

SITE 5

PETROLEUM PROCESS HEATER

Location No. SITE # 5 Unit No. H-20

Unit Description

VERTICAL NATURAL-DRAFT HEATER

Installation Date N/A

Heater Rating

Burner Description TEN (10) JOHN ZINK LNC-PC-10 LOW NOX BURNERS

Test Fuel Combinations #6 OIL & REFINERY GAS

Fuel Temp. at Burner (°F) APPX 170°F

Primary Air Temp. (°F) AMBIENT

Comments:

MOBILE LABORATORY DATA Test No.________

Test No.__________ Date 11-7-80 Location__________ Engr. H. Brening

Unit No. H-20 Fuel NO. 6 + Gas Capacity__________

Unit Type Vert. Heater Burner Type Zink DB

	5-1		5-2				
1. Test No.	1s Front		1s Front				
2. Date 11-7-80							
3. Time	0935		1035				
4. Load							
5. Process Rate							
6. Flue Diam. or Size, ft							
7. Probe Position Center							
8. Oxygen (%)	7.6		7.8				
9. NOx (hot) read/3% O_2 (ppm)*	219		220				
10. NO (hot) read/3% O_2 (ppm)*	218		220				
11. NO_2 (hot) read/3% O_2 (ppm)*	1		0				
12. NO (cold) read/3% O_2 (ppm)*	258	347	260	355			
13. Carbon Dioxide (%)	8.8%		8.4%				
14. Carbon Monoxide (ppm) uncor/cor*	10	13	10	14			
15. Hydrocarbon (ppm) uncor/cor*	5		0				
16. Sulfur Dioxide (ppm) uncor/cor*	310		280				
17. Smoke Spot (Bacharach)							
18. Atmos. Temp. (°F/°C)	69		69				
19. Dew Point Temp. (°F/°C)							
20. Atmos. Pressure (in. Hg)	30.16		30.16				
21. Relative Humidity (%)	60%		60%				
22.							
23.							
24.							
25.							
26.							
27.							
28.							
29.							
30.							

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.

Test No. ______ Date 11·10·80 Location ______ Engr. H. Buening

Unit No. H·20 Fuel No6 & Gas Capacity ______

Unit Type Vert. Heater Burner Type Zink

	5·3		5·4		5·5		5·6		5·7	
1. Test No.	As Found		Stack Damper Adjustment		Stack Damper Adjustment		Stack Damper Adjustment		As Found	
2. Date 11/10/80										
3. Time	1330		1430		1515		1620		1645	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	7.7		6.9		5.7		4.4		7.6	
9. NOx (hot) read/3% O_2 (ppm)*	230		221		229		226		226	
10. NO (hot) read/3% O_2 (ppm)*	228		221		228		223		226	
11. NO_2 (hot) read/3% O_2 (ppm)*	2		0		1		3		0	
12. NO (cold) read/3% O_2 (ppm)*	260	352	270	345	285	335	279	303	267	359
13. Carbon Dioxide (%)	8.6%		9.6		10.6		11.8		9.0%	
14. Carbon Monoxide (ppm) uncor/cor*	8	11	9	11	10	12	20	22	8	11
15. Hydrocarbon (ppm) uncor/cor*	0		0		0		0		0	
16. Sulfur Dioxide (ppm) uncor/cor*	300		340		390		415		338	
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	70°F		70°		69°		67°			
19. Dew Point Temp. (°F/°C)	59°F		59°		59°		58°			
20. Atmos. Pressure (in. Hg)	29.95		29.95		29.94		29.92			
21. Relative Humidity (%)	51%		51%		54%		59%			
22.										
23.	As Found		Stack Damper Adjustment		Stack Damper Adjustment		Stack Damper Adjustment		Base Line As Found	
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA Test No.________

Test No.__________ Date 11-11-80 Location______________ Engr. H Baering

Unit No. H-20 Fuel #6 & Gas Capacity 14 000 BPD

Unit Type Vert Heater Burner Type Zink low Nox

	5-8		5-9		5-10		5-11		5-12	
1. Test No.	AM As Found		1st Register Adjust.		Register Adjust					
2. Date 11-11-80										
3. Time	9:30		1045		1300		1400		1450	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position										
8. Oxygen (%)	8.0%		8.1%		7.2%		6.3%		6.4%	
9. NOx (hot) read/3% O_2 (ppm)*	224		219		213		222		222	
10. NO (hot) read/3% O_2 (ppm)*	223		217		211		221		220	
11. NO_2 (hot) read/3% O_2 (ppm)*	1		2		2		1		2	
12. NO (cold) read/3% O_2 (ppm)*	264	366	257	358	252	329	270	331	270	333
13. Carbon Dioxide (%)	8.6%		8.8%		9.2%		10.0%		10.0%	
14. Carbon Monoxide (ppm) uncor/cor*	8	11	5	7	5	7	5	6	8	10
15. Hydrocarbon (ppm) uncor/cor*	0		0		0		0		0	
16. Sulfur Dioxide (ppm) uncor/cor*	340		340		360		365		380	
17. Smoke Spot (Bacharach)	-		-		-		-			
18. Atmos. Temp. (°F/°C)	61°F		61°F		68°		68°			
19. Dew Point Temp. (°F/°C)	54°F		54°F		58°		58°			
20. Atmos. Pressure (in. Hg)	30.04		30.05		30.01		30.02			
21. Relative Humidity (%)	63%		63%		55%		55%			
22.			1st Register Adjust.							
23.					Air Register Adjustment					
24.	Am As Found Conditions						Register & Stack Damper adjustment		Damper adjustment	
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.________

Test No.________ Date 11-12-80 Location________________ Engr. KM

Unit No. H-20 Fuel #6 & Gas Capacity________________

Unit Type Vert. Heater Burner Type Zink low NOx

1. Test No.	SR-13		SR-14				
2. Date 11-12-80							
3. Time	1045		1120				
4. Load							
5. Process Rate							
6. Flue Diam. or Size, ft							
7. Probe Position Center							
8. Oxygen (%)	7.4%		5.9				
9. NOx (hot) read/3% O_2 (ppm)*	179		172				
10. NO (hot) read/3% O_2 (ppm)*	178		168				
11. NO_2 (hot) read/3% O_2 (ppm)*	1		4				
12. NO (cold) read/3% O_2 (ppm)*	218	289	217	259			
13. Carbon Dioxide (%)	8.02		8.4				
14. Carbon Monoxide (ppm) uncor/cor*	6	8	17	20			
15. Hydrocarbon (ppm) uncor/cor*	0		0				
16. Sulfur Dioxide (ppm) uncor/cor*	220		245				
17. Smoke Spot (Bacharach)							
18. Atmos. Temp. (°F/°C)	60°F		61°F				
19. Dew Point Temp. (°F/°C)	53°F		54°F				
20. Atmos. Pressure (in. Hg)	30.22						
21. Relative Humidity (%)	69%		64°F				
22.	As Found High Air Flow						
23.			Partic. Test				
24.							
25.							
26.							
27.							
28.							
29.							
30.							

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA **Test No.** 5-1

Test No. 5-1 **Date** 11-7-80 **Location** SITE #5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD.

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-1				
2.Date	11-7-80				
3.Time	9:35				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH X 58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPH X 58.33)	130.3				
9. VENT GAS TO HEATER (SCFH)	2450				
10.Stack Temp °F	924				
11.Stack Damper % OPEN	100%				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H_2S IN VENT GAS (P.P.M)	<.100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	100	100	100	100	100	100	100	100		
Sec Regist	100	100	100	100	100	100	100	100	100	100		
Tert *(% Open)	100	100	100	100	100	100	100	100	100	100		
20.	TEMP	°F										
21. FIREBOX	1214											
22. CRUDE IN	359											
23. CRUDE OUT	656											
24. CRUDE CROSSOVER	496											
25.												
26. COMMENTS												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-2

Test No. 5-2 Date 11-7-80 Location SITE # 5 Engr. H.B

Unit No. H-20 Fuel #6 OIL & REFINERY GAS Capacity 14000 BPD

Unit Type VERTICAL HEATER Burner Type JOHN ZINK LNC-PC-10

1.Test Number	5-2				
2.Date	11-7-80				
3.Time	10:35				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BAHX58.33)	379				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BAHX58.33)	123				
9. VENT GAS TO HEATER (SCFH)	2500				
10.Stack Temp °F	920				
11.Stack Damper % OPEN	100				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H_2S IN VENT GAS (P.P.M)	7 100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	100	100	100	100	100	100	100	100		
Sec Regist	100	100	100	100	100	100	100	100	100	100		
Tert *(% Open)	100	100	100	100	100	100	100	100	100	100		
20.	TEMP	°F										
21. FIREBOX	1205											
22. CRUDE IN	359											
23. CRUDE OUT	654											
24. CRUDE CROSSOVER	496											
25.												
26. COMMENTS:	TEST CONDITION AS FOUND.											
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-3

Test No. 5-3 **Date** 11-10-80 **Location** SITE # 5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-3				
2.Date	11-10-80				
3.Time	13:30				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BAHX58.33)	379				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BAHX58.3)	116.6				
9. VENT GAS TO HEATER (SCFH)	2525				
10.Stack Temp °F	920				
11.Stack Damper % OPEN	100				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H_2S IN VENT GAS (P.P.M)	>100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	100	100	100	100	100	100	100	100		
Sec Regist	100	100	100	100	100	100	100	100	100	100		
Tert *(% Open)	100	100	100	100	100	100	100	100	100	100		
20.	TEMP	°F										
21. FIREBOX	1184											
22. CRUDE IN	360											
23. CRUDE OUT	652											
24. CRUDE CROSSOVER	492											
25.												
26. COMMENTS	TEST COND: AS FOUND											
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-4

Test No. 5-4 **Date** 11-10-80 **Location** SITE #5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-4				
2.Date	11-10-80				
3.Time	14:40				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH X 58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPH X 58.33)	113				
9. VENT GAS TO HEATER (SCFH)	2475				
10.Stack Temp °F	906				
11.Stack Damper % OPEN	70%				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H_2S IN VENT GAS (P.P.M)	7-100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	100	100	100	100	100	100	100	100		
Sec Regist	100	100	100	100	100	100	100	100	100	100		
Tert *(% Open)	100	100	100	100	100	100	100	100	100	100		
20.	TEMP	°F										
21. FIREBOX	1192											
22. CRUDE IN	361											
23. CRUDE OUT	650											
24. CRUDE CROSSOVER	488											
25.												

26. COMMENTS	STACK DAMPER ADJ.
27.	ALL REGISTER 100% OPEN
28.	
29.	
30.	

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-5

Test No. 5-5 Date 11-10-80 Location SITE #5 Engr. H.B

Unit No. H-20 Fuel #6 OIL & REFINERY GAS Capacity 14000 BPD

Unit Type VERTICAL HEATER Burner Type JOHN ZINK LNC-PC-10

1.Test Number	5-5				
2.Date	11-10-80				
3.Time	15:15				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH X 58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPH X 58.33)	106.3				
9. VENT GAS TO HEATER (SCFH)	2400				
10.Stack Temp °F	879				
11.Stack Damper % OPEN	65%				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H₂S IN VENT GAS (P.P.M)					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	—	—	—	—	—	—	→			
Sec Regist	100	100	—	—	—	—	—	—	→			
Tert *(% Open)	100	100	—	—	—	—	—	—	→			
20.	TEMP	°F										
21. FIREBOX	1179											
22. CRUDE IN	360											
23. CRUDE OUT	652											
24. CRUDE CROSSOVER	484											
25.												

26. COMMENTS	
27.	STACK DAMPER ADJ
28.	
29.	
30.	

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 5-6

Test No. 5-6 **Date** 11-10-80 **Location** SITE # 5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-6				
2.Date	11-10-80				
3.Time	16:20				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPHX58.33)	376				
7. FUEL OIL PRESS(PSIG)	70				
8. FUEL OIL TO HEATER (BPHX58.33)	102.8				
9. VENT GAS TO HEATER (SCFH)	2400				
10.Stack Temp °F	854				
11.Stack Damper % OPEN	60%				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H2S IN VENT GAS (P.P.M)	>100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	—	—	—	—	—	—	—	→		
Sec Regist	100	100	—	—	—	—	—	—	—	→		
Tert *(% Open)	100	100	—	—	—	—	—	—	—	→		
20.	TEMP	°F										
21. FIREBOX	1170											
22. CRUDE IN	360											
23. CRUDE OUT	647											
24. CRUDE CROSSOVER	478											
25.												
26. COMMENTS												
27.												
28.												
29.												
30.												

*** O.O.S. - OUT OF SERVICE**

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 5-7

Test No. 5-7 **Date** 11/10/80 **Location** SITE # 5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-7				
2.Date	11-10-80				
3.Time	16:45				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPHY58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPHY58.33)	123.4				
9. VENT GAS TO HEATER (SCFH)	2350				
10.Stack Temp °F					
11.Stack Damper % OPEN	100%				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H_2S IN VENT GAS (P.P.M)	7100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100								→		
Sec Regist	100	100								→		
Tert *(% Open)	100	100								→		
20.	TEMP	°F										
21. FIREBOX	1176											
22. CRUDE IN	360											
23. CRUDE OUT	649											
24. CRUDE CROSSOVER	489											
25.												
26. COMMENTS:												
27.												
28.												
29.												
30.												

*** O.O.S. - OUT OF SERVICE**

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-8

Test No. 5-8 Date 11-11-80 Location SITE #5 Engr. H.B

Unit No. H-20 Fuel #6 OIL & REFINERY GAS Capacity 14000 BPD

Unit Type VERTICAL HEATER Burner Type JOHN ZINK LNC-PC-10

1.Test Number	5-8				
2.Date	11-11-80				
3.Time	09:30				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH×58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPH×58.33)	129				
9. VENT GAS TO HEATER (SCFH)	2250				
10.Stack Temp °F	921 °F				
11.Stack Damper % OPEN	100%				
12. OPACITY	0				
13.COMMENTS:					
14 Burner OOS	NONE				
H_2S IN VENT GAS (P.P.M)	7100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	—	—	—	—	—	—	—	→		
Sec Regist	100	100	—	—	—	—	—	—	—	→		
Tert *(% Open)	100	100	—	—	—	—	—	—	—	→		
20.	TEMP	°F										
21. FIREBOX	1179											
22. CRUDE IN	358											
23. CRUDE OUT	649											
24. CRUDE CROSSOVER	490											
25.												
26. COMMENTS:	TEST COND: AS FOUND											
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 5-9

Test No. 5-9 **Date** 11-11-80 **Location** SITE #5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-9				
2.Date	11-11-80				
3.Time	10:45				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH X 58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPH X 58.33)	126.8				
9. VENT GAS TO HEATER (SCFH)	2200				
10.Stack Temp °F	911				
11.Stack Damper % OPEN	100				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS	NONE				
H_2S IN VENT GAS (P.P.M)	>100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	75	100	75	50	50	50	50	50	75	75		
Sec Regist	STUCK 100	100	75	50	75	75	75	75	50	50		
Tert *(% Open)	100	100	100	100	100	100	100	100	100	100		
20.	TEMP	°F										
21. FIREBOX	1167											
22. CRUDE IN	358											
23. CRUDE OUT	647											
24. CRUDE CROSSOVER	486											
25.												

26. COMMENTS:	REGISTER ADJ.
27.	
28.	
29.	
30.	

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-10

Test No. 5-10 **Date** 11-11-80 **Location** SITE # 5 **Engr.** H.B
Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD
Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-10				
2.Date	11-11-80				
3.Time	13:00				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BAHX58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BAHX58.33)	121.7				
9. VENT GAS TO HEATER (SCFH)	23.0				
10.Stack Temp °F	897				
11.Stack Damper % OPEN	100 %				
12. OPACITY	0				
13.COMMENTS:					
14.Burner OOS					
H2S IN VENT GAS (P.P.M)	>100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	75	STUCK 100	60	50	50	50	50	50	50	60		
Sec Regist	50	STUCK 100	75	55	50	60	50	50	50	50		
Tert *(% Open)	100	80	STUCK 100	75	50	STUCK 80	70	60	70	70		
20.	TEMP	°F										
21. FIREBOX	1181											
22. CRUDE IN	359											
23. CRUDE OUT	651											
24. CRUDE CROSSOVER	484											
25.												
26. COMMENTS												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. 5-11

Test No. 5-11 **Date** 11-11-80 **Location** SITE# 5 **Engr.** H.B
Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD
Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-11				
2.Date	11-11-80				
3.Time	14:00				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH×58.33)	376				
7. FUEL OIL PRESS(PSIG)	70				
8. FUEL OIL TO HEATER (BPH×58.33)	120				
9. VENT GAS TO HEATER (SCFH)	2325				
10.Stack Temp °F	888				
11.Stack Damper % OPEN	70%				
12. OPACITY	0				
13.COMMENTS:	REGISTER &	DAMPER	ADJ		
14.Burner OOS	NONE				
H_2S IN VENT GAS (P.P.M)					

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	75	STUCK 100	60	50	50	50	50	50	50	60		
Sec Regist	50	STUCK 100	75	55	50	60	50	50	50	50		
Tert *(% Open)	100	80	STUCK 100	75	50	STUCK 80	70	60	70	70		
20.	TEMP	°F										
21. FIREBOX												
22. CRUDE IN												
23. CRUDE OUT												
24. CRUDE CROSSOVER												
25.												
26. COMMENTS:	LONG FLAMES LAZY ON THE ENDS AND IMPINGING ON											
27.	CEILING, LOWEST O_2 with this REGISTER SETTING 6.3% O_2											
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 5-12

Test No. 5-12 **Date** 11-11-80 **Location** SITE #5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-12				
2.Date	11-11-80				
3.Time	14:50				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPH×58.33)	376				
7. FUEL OIL PRESS (PSIG)	70				
8. FUEL OIL TO HEATER (BPH×58.33)	123				
9. VENT GAS TO HEATER (SCFH)	2325				
10.Stack Temp °F	899				
11.Stack Damper % OPEN	70				
12. OPACITY	0				
13.COMMENTS: STACK DAMP	OPEN				
14.Burner OOS	NONE				
H_2S IN VENT GAS (P.P.M)	>100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	→									
Sec Regist	100	100	→									
Tert *(% Open)	100	100	→									
20.	TEMP	°F										
21. FIREBOX	1182											
22. CRUDE IN	359											
23. CRUDE OUT	652											
24. CRUDE CROSSOVER	484											
25.												
26. COMMENTS:												
27.												
28.												
29.												
30.												

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 5-13

Test No. 5-13 **Date** 11-12-80 **Location** SITE # 5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

1.Test Number	5-13				
2.Date	11-12-80				
3.Time	12:45				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BAIY58.33)	376				
7. FUEL OIL PRESS (PSIG)	63				
8. FUEL OIL TO HEATER (BAIY58.33)	75				
9. VENT GAS TO HEATER (SCFH)	4975				
10.Stack Temp °F	937				
11.Stack Damper % OPEN	100%				
12. OPACITY	0				
13.COMMENTS: AS FOUND					
14.Burner OOS	NONE				
H_2S IN VENT GAS (P.P.M)	7100				

Burner No.	1	2	3	4	5	6	7	8	9	10	11	12
Prim Regist	100	100	→	→	→	→	→	→	→	→		
Sec Regist	100	100	→	→	→	→	→	→	→	→		
Tert *(% Open)	100	100	→	→	→	→	→	→	→	→		
20.	TEMP	°F										
21. FIREBOX	1257											
22. CRUDE IN	367											
23. CRUDE OUT	665											
24. CRUDE CROSSOVER	496											
25.												

26. COMMENTS: HIGH GAS FLOW

27. FURNACE DRAFT INCH OF WATER -.1

28.

29.

30.

* O.O.S. - OUT OF SERVICE

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** 5-14

Test No. 5-14 **Date** 11-12-80 **Location** SITE#5 **Engr.** H.B

Unit No. H-20 **Fuel** #6 OIL & REFINERY GAS **Capacity** 14000 BPD

Unit Type VERTICAL HEATER **Burner Type** JOHN ZINK LNC-PC-10

	PARTICULATE TEST				
1.Test Number	5-14				
2.Date	11-12-80				
3.Time	11:20				
4.Load					
5.Process Rate					
6. CRUDE CHARGE (BPHX58.33)	376				
7. FUEL OIL PRESS (PSIG)	50				
8. FUEL OIL TO HEATER (BPHX58.33)	65				
9. VENT GAS TO HEATER (SCFH)	4800				
10.Stack Temp °F	916				
11.Stack Damper % OPEN	65%				
12. OPACITY	0				
13.COMMENTS: DAMPER ADJ.					
14.Burner OOS	NONE				
H_2S IN VENT GAS (P.P.M)	7100				

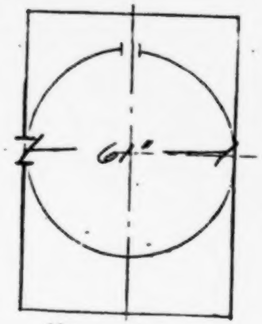
Burner No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Prim Regist	100	100								→		
Sec Regist	100	100								→		
Tert *(% Open)	100	100								→		
20.	TEMP	°F										
21. FIREBOX	1244											
22. CRUDE IN	362											
23. CRUDE OUT	666											
24. CRUDE CROSSOVER	491											
25.												
26. COMMENTS	PARTICULATE TEST — HIGH GAS FLOW											
27.												
28.												
29.												
30.												

*** O.O.S. - OUT OF SERVICE**

Data Sheet 6002-1

SMOKESTACK FLOW PROFILE

T NO. /
LOCATION NO.
DATE 11-12-80
SAMPLING LOCATION Stack
INSIDE OF FAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE A) ______ BAROMETRIC PRESS, in.Hg 30.02
INSIDE OF NEAR WALL TO
OUTSIDE OF NIPPLE, (DISTANCE B) ______ STACK PRESS., Ps, iwg -.12
STACK I.D. (DISTANCE A - DISTANCE B) ____ STK. GAS SP. GRAVITY, G_S ____
NEAREST UPSTREAM DISTURBANCE
NEAREST DOWNSTREAM DISTURBANCE



Nippe 6"

Area = 20.29 ft²

TRAVERSE POINT NUMBER	% OF STACK DIAMETER	DISTANCE FROM INSIDE WALL	VELOCITY HEAD (ΔP_s), in. H_sO	STACK TEMPERATURE (T_s, °F	OXYGEN %	STACK GAS SPEED, Vs ft/min
1.	4.4	2.5"	.05			
2.	14.7	9"	.06			
3.	29.5	18"	.04	916		
4.	70.5	43"	.05			
5.	85.3	52"	.075			
	95.6	58"	.09			
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
Average			.0608	916		

STACK GAS SPEED, $V_s = 174\ F_s \sqrt{\overset{\text{Average}}{\Delta P}(T_s + 460)\ (\frac{407}{P_s})\ (\frac{1.00}{G_s})}$

60-23
rev. 11/74

KVB

Test No. 5-14
Engr. /(c

STACK DATA

Date 11-12-80 Location ____ Unit No. H-20 Fuel #6 & Gas
Load ____ K#/hr or MBtu/hr ____ Filter No. B
Sample Box No. ____ Meter Box No. ____ Probe No. ____ Probe Length ____
Stack Moisture 10 estm %
Ambient Temperature 65 °F
Nozzle Diameter .5 in.
Atmospheric Pressure 30.02 in.Hg
Stack Gas Pressure, Ps -.12 iwg
Stack Area, As 20.29 ft^2

Remarks:
Final Meter: 2120.41
Initial Meter: 2079.05

10 min per pt

Time	Vm (CF)	Vacuum (in. Hg)	ΔP (iwg)	ΔH (iwg)	T_s (°F)	$T_{imp.in}$ (°F)	$T_{imp.out}$ (°F)	T_{filter} (°F)	T_m (°F) OUT / IN
1.	2086.31	6.0	.05	1.06	916	63°	168°	250°	86 / 86
2.	2093.47	6.7	.06	1.06	916	59	210	340	84 / 90
				@ 29 min					
3.	2100.37	6.5	.04	1.00	916	58	210	340	84 / 94
4.	2107.20	6.5	.05	1.00	916	60	224	320	87 / 97
				@ 45 min .90					
5.	2113.89	6.2	.075	.90	916	64	232	320	87 / 97
6.	2120.41	6.2	.09	.90	916	65	236	325	87 / 98
TOTAL									
AVER.			.06	1.0	916				90

Rev. 5/79

A Research-Cottrell Company

PARTICULATE CALCULATION SHEET

Test No. 5- 14 (Inlet, Outlet)
Box No.
Test Description:

Location
Test Date 11-12-80

Dry Gas Meter Vol (ft3)
Final 2120.41
Initial 2079.05
Total 41.36 ✓

Impinger Water Vol (ml)

	1	2	3	~~Total~~ 4	Tot.
Final	192	120	1	210.4	
Initial	100	100	0	200	
△ Vol	92	·20	1	10.4	123.4

					Filter No.	Blank No.
Beaker No.	4				B	
Date Weighed						
Tare Wt. 1	101.0798					
2	101.0797					
3	101.0797					
4						
5						
6						
Avg	101.0797				.7635	
Bottle No.						
Content Impinger (Water)	Probe (Acetone)	Probe (Water)	Cyclone (Acetone)	Flask (Dry)		
Rinse (ml)	450					
te Weighed or 250 Bake)						
Final Wt. 250 1	101.0944					
2	101.0944				.8393	
3	101.0943				.8397	
4					.8396	
5						
6						
Avg	101.0944				.8395	
Residue Wt Final 250 Tare)	.0147				.0076	
Date Weighed or 650 Bake)						
Final Wt. 650 1						
2						
3						
4						
5						
6						
Avg						
Residue Wt. Final 650 Tare)						

Comments: Acet. Blank
.0014g / 200ml

$$\begin{array}{r} .0076 \\ +.0147 \\ \hline .0907 \\ -.0032 \\ \hline .0875 \end{array}$$

PARTICULATE EMISSION CALCULATIONS

Test No. 5-14 Date 11-12-80 Location _____ Engr. _____

Unit No. H-20 Fuel #6 & Gas Sampling Train and Method 5

Pitot Factor, Fs .83 Barometric Pressure, P_{bar} 30.02 ✓ (STO 0) in. Hg

Tot. Liquid Collected, V_{1c} 123.4 ✓ (STO 1) ml Total Particulate, M_n 87.5 ✓ (STO 2) m gm

Velocity Head, ΔP .06 ✓ (STO 3) iwg Stack Temp., Ts 916 ✓ (STO 4) °F Stack Area, As 20.29 ✓ (STO 5) ft^2

Sample Volume, Vm 41.36 ✓ (STO 6) ft^3 Stack Press., Psg -.12 ✓ (STO 7) iwg Excess O_2, XO_2% 5.9 ✓ (STO 8) %

Orifice Press. Diff., H 1.0 ✓ (STO 9) iwg Stack Gas Sp. Gravity, Gs 1.0 ✓ (STO A) n.d.

Sample Time, θ 60 ✓ (STO B) min Nozzle Dia., Dn .5 ✓ (STO C) in. Meter Temp., T_m 90 ✓ (STO D) °F

Select F_e	Oil (A)	Gas (B)	Coal (C)	Other:
SC Feet/10^4 Btu	92.2	87.4	98.2	90.136 (D)

Press [✓ (E)] if meter is not temperature compensated.

1. Sample Gas Volume $Vm_{std} = 0.0334\ Vm(P_{bar} + H/13.6)$ 40.06 ✓ SCF
2. Water Vapor $Vw_{std} = 0.0474\ V_{1c}$ 5.85 ✓ SCF
3. Moisture Content $Bwo = Eq.\ 2/(Eq.\ 1 + Eq.\ 2)$ .13 ✓ N.D.
4. Concentration a. $C = 0.0154\ Mn/Vm_{std}$ .0337 ✓ grains/DSCF

   b. $C = 2.205 \times 10^{-6}\ Mn/Vm_{std}$ 4817×10^{-6} ✓ lb/DSCF

   c. $C = Eq.\ 4b \times 16.018 \times 10^3$ .0772 ✓ grams/DSCM
5. Abs. Stack Press. $Ps = P_{bar} \times 13.6 + Psg$ 408.15 ✓ in. w abs.
6. Stack Gas Speed $Vs = 174\ Fs \sqrt{\Delta P Ts} \sqrt{\frac{407}{Ps} \times \frac{1.00}{Gs}}$ 1310.4 ✓ ft/min
7. Stack Gas Flow Rate @ 70°F a. $Qsw = Eq.\ 6 \times As \times \frac{530}{Ts} \times \frac{Ps}{407}$ 10268 ✓ WSCF/min

   b. $Qsd = Eq.\ 7a \times (1. - Eq.\ 3)$ 8960 ✓ DSCF/min
8. Material Flow $Ms = Eq.\ 7b \times Eq.\ 4b \times 60$ 2.59 ✓ lb/hr
9. XO_2 factor $XO_2f = 2090/(20.9 - XO_2\%)$ 139.33 ✓ N.D.
10. Emission a. $E = Eq.\ 4b \times Fe \times Eq.\ 9$ .0665 ✓ lb/MMBtu

    b. $E = Eq.\ 4c \times Fm \times Eq.\ 9 \times 1000$ 26.01 ng/joule
11. % Isokinetic $I = \frac{14077 \times Ts(Vm_{std} + Vw_{std})}{\theta \times Vs \times Ps \times Dn^2}$ 110.84 %

*If calculating by hand:

1) Convert T_S and T_m to °R
2) Multiply EQ 1 by $530/T_m$(°R) if meter not temperature compensated.
3) $F_m = 2.684 \times 10^{-5} \times Fe$

Data Sheet 6002-4
Revised 2/15/78

FUEL ANALYSIS, OIL FUEL, TEST SITE 5

Ultimate Analysis:	
Carbon, %	85.92
Hydrogen, %	11.34
Nitrogen, %	0.81
Sulfur, %	1.00
Ash, %	0.043
Oxygen, % (by difference)	0.89
Heat of Combustion:	
Gross Btu/lb	18,530
Net Btu/lb	17,500
API Gravity @ 60°F	14.5

SITE 6

PETROLEUM PROCESS HEATER

Location No. SITE # 6 **Unit No.** 53A

Unit Description -Reformer Heater (Rectangular, Wall-Fired)
-Balanced Draft
-Preheated Combustion Air

Installation Date SEPTEMBER, 1980

Heater Rating 132 m^3/h (20,000 bbl/d)

Burner Description (8) CEA LOW-NO_x "VENTURI" BURNERS

Test Fuel Combinations REFINERY GAS

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) 520°

Comments:

A = SITE 6

MOBILE LABORATORY DATA

Test No. A/2

Test No. A/1 Date 12-8-80 Location ______ Engr. J. Hart

Unit No. H-53A Fuel Ref. Gas Capacity 20 000 bbl/day

Unit Type crude reformer heater Burner Type CEA / Venturi

1. Test No.	A/1-1		A/1-2		A/1-3		A/1-4		A/2-1	
2. Date 12-8-80										
3. Time	1005		1040		1140		1350		1430	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	4.8		4.1		3.2		2.9		2.5	
9. NOx (hot) read/3% O_2 (ppm)*	88	-	81	-	78		70	-	68	-
10. NO (hot) read/3% O_2 (ppm)*	87	-	79	-	78		65	-	64	-
11. NO_2 (hot) read/3% O_2 (ppm)*	1	-	2	-	0		5	-	4	-
12. NO (cold) read/3% O_2 (ppm)*	97	108	97	103	96	97	92	91	89	87
13. Carbon Dioxide (%)	8.2		8.1		9.7		14.7		13.6	
14. Carbon Monoxide (ppm) uncor/cor*	8	9	8	9	8	8	8	8	6	6
15. Hydrocarbon (ppm) uncor/cor*	5	-	2	-	0	-	0	-	3	-
16. Sulfur Dioxide (ppm) uncor/cor*	8	-	0	-	0	-	14	-	18	-
17. Smoke Spot (Bacharach)	-		-				-			
18. Atmos. Temp. (°F/°C)	54°F		55		47		47		47	
19. Dew Point Temp. (°F/°C)	45°F		45		57		57		57	
20. Atmos. Pressure (in. Hg)	30.26		30.26		30.26		30.23		30.26	
21. Relative Humidity (%)	49%		46%		46%		46%		46%	
22.										
23.										
24.	Base Line (As Found)						Base Line (Min. O2)			
25.			Base Line		Base Line (Low O2)					
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No.________

Test No. A/3 Date 12-8-80 Location________ Engr. HART

Unit No. H-53A Fuel Ref. Gas Capacity 20000 bbl/day

Unit Type crude reformer heater Burner Type CEA / Venturi

1. Test No.	A/3-1		A/3-2		A/3-3					
2. Date 12/8/80										
3. Time	1445		1500		1530					
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position										
8. Oxygen (%)	2.7		2.5							
9. NOx (hot) read/3% O_2 (ppm)*			34	-						
10. NO (hot) read/3% O_2 (ppm)*			32	-						
11. NO_2 (hot) read/3% O_2 (ppm)*			2	-						
12. NO (cold) read/3% O_2 (ppm)*	45	44	43	42						
13. Carbon Dioxide (%)	14.6		14.4							
14. Carbon Monoxide (ppm) uncor/cor*	110	108	30	29						
15. Hydrocarbon (ppm) uncor/cor*	10	-	0	-						
16. Sulfur Dioxide (ppm) uncor/cor*	18		17	-						
17. Smoke Spot (Bacharach)										
18. Atmos. Temp. (°F/°C)	47		47		47					
19. Dew Point Temp. (°F/°C)	57		57		57					
20. Atmos. Pressure (in. Hg)	30.24		30.24		30.24					
21. Relative Humidity (%)	46%		46%		46%					
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA **Test No.** A/4-

Test No.________ **Date** 12/12/80 **Location**________ **Engr.**________

Unit No.________ **Fuel** Ref. Gas **Capacity**________

Unit Type________ **Burner Type** C.E.A.

1. Test No.	A/4-1		A/4-2		A/4-3		A/5-1		A/5-2	
2. Date 12/12/80										
3. Time	0920		0935		1045		1120		1210	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	2.4		2.5		2.3		3.5		4.1	
9. NOx (hot) read/3% O_2 (ppm)*	49		47	-	46	-	60	-	92	-
10. NO (hot) read/3% O_2 (ppm)*	47		46	-	43	-	57	-	68	-
11. NO_2 (hot) read/3% O_2 (ppm)*	2		1	-	3	-	3	-	4	-
12. NO (cold) read/3% O_2 (ppm)*	57	55	53	52	52	50	73	75	90	96
13. Carbon Dioxide (%)	11%		11.4		11.6		11.4		10.2	
14. Carbon Monoxide (ppm) uncor/cor*	16	15	18	18	18	17	11	11	10	11
15. Hydrocarbon (ppm) uncor/cor*	8		8	-	0	-	0	-	0	-
16. Sulfur Dioxide (ppm) uncor/cor*	20		14	-	12	-	14	-	18	-
17. Smoke Spot (Bacharach)	-		-		-		-		-	
18. Atmos. Temp. (°F/°C)	42		42°		42°		47°		47°	
19. Dew Point Temp. (°F/°C)	41°		41°		41°		49		49°	
20. Atmos. Pressure (in. Hg)	30.10		30.10		30.09		30.07		30.07	
21. Relative Humidity (%)	92%		92%		92%		86%		86%	
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA **Test No.** A/5

Test No.________ **Date** 12/12/80 **Location**________ **Engr.** J. Hart

Unit No.________ **Fuel** Ref. Gas **Capacity**________

Unit Type________ **Burner Type**________

1. Test No.	A/5-3		A/5-4		A/5-5					
2. Date 12/12/80										
3. Time	1255		1320		1355					
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	4.8		5.7		3.3					
9. NOx (hot) read/3% O_2 (ppm)*	84	-	94	-	67	-				
10. NO (hot) read/3% O_2 (ppm)*	78	-	88	-	66	-				
11. NO_2 (hot) read/3% O_2 (ppm)*	6	-	6	-	1	-				
12. NO (cold) read/3% O_2 (ppm)*	103	114	118	139	83	84				
13. Carbon Dioxide (%)	9.9%		9.4		11.4					
14. Carbon Monoxide (ppm) uncor/cor*	10	11	0	0	10	10				
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-	0	-				
16. Sulfur Dioxide (ppm) uncor/cor*	10	-	14	-	12	-				
17. Smoke Spot (Bacharach)	-		-		-					
18. Atmos. Temp. (°F/°C)	57		57		57					
19. Dew Point Temp. (°F/°C)	51		51		51					
20. Atmos. Pressure (in. Hg)	30.05		30.05		30.05					
21. Relative Humidity (%)	67		67		67					
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA . **Test No.** A/1-A/2

Test No. A/1-A/2 **Date** 12-8-80 **Location** SITE #6 **Engr.** TIDONA/HART

Unit No. H-53-A **Fuel** REFINERY GAS **Capacity** 20,000 BBL/DAY

Unit Type Crude Reformer Heater **Burner Type** CEA VENTURI

1. Test Number	A/1-1	A/1-2	A/1-3	A/1-4	A/2-1
2. Date	12-8-80	12-8-80	12-9-80	12-8-80	12-8-80
3. Time	10:05	10:40	1140	1350	1430
4. Load 10^3 BBL/DAY	20	20			
5. Process Rate					
6. TOTAL FUEL TO 4 NTS. 10^6 B/h	4.5 (3600)	4.5 (360)	4.7 (3760)	4.65 (3720)	4.6 (3680)
7. TEMP OUT (°F)	858	853	857	857	858
8. TEMP IN (°F)	747	743	742	741	740
9. O_2 HEATER %	5.0	5.7	5.0	5.0	4.4
10. NG FLOW N %	46	49	50.5	50.5	50
11. GAS P N (PSIG)	2	2	2.2	2.2	2.1
12. COMB AIR N %	45	54	49	50	67
13. NG FLOW S %	45	47	47	47	47
14. GAS P S (PSIG)	2.5	2	2.6	2.5	2.5
15. COMB AIR S %	42	50	46	45.5	56
16. TEMP FLUE GAS HEATER OUT °F	1285	1315	1335	1321	1327
17. TEMP FLUE GAS AH IN °F	635	619	617	616	615
18. TEMP FLUE GAS AH OUT °F	309	312	323	326	327
19. TEMP AMBIENT AH IN °F	54	55			
20. TEMP AIR AH OUT °F	525	525	525	526	527
21.					
22. BURNER OUT OF SERVICE					
23.					
24. COMMENTS :	BASELINE	BASELINE	LOW O_2	NOM. O_2	LOW O_2
25.	(AS FOUND)				ON SOUTH SIDE
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. A/3

Test No. A/3 **Date** 12-8-80 **Location** SITE # C **Engr.** TIDONA / HART

Unit No. H-53-A **Fuel** REFINERY GAS **Capacity** 20,000 BBL/DAY

Unit Type Crude Reformer Heater **Burner Type** CEA VENTURI

1. Test Number	A/3-1	A/3-2A	A/3-2B		
2. Date	12-8-80	12-8-80	12-8-80		
3. Time	14:45	1450	1500		
4. Load					
5. Process Rate 10^3 BBL/d	20	20	20		
6. TOTAL FUEL TO 4 HTS. [illegible]/d	4.5 (360)	4.4 (360)	4.5 (360)		
7. TEMP OUT (°F)	860	858	858		
8. TEMP IN (°F)	741	740	739		
9. O_2 HEATER %	2.0	2.0	2.0		
10. NG FLOW N %	50	48	48		
11. GAS P N (PSIG)	2	2	2		
12. COMB AIR N %	54	54	54		
13. NG FLOW S %	46	46	46		
14. GAS P S (PSIG)	2.5	2.5	2.5		
15. COMB AIR S %	58	60	60		
16. TEMP FLUE GAS HEATER OUT °F	1342	1332	1321		
17. TEMP FLUE GAS AH IN °F	616	613	613		
18. TEMP FLUE GAS AH OUT °F	327	327	327		
19. TEMP AMBIENT AH IN °F	526	526	525		
20. TEMP AIR AH OUT °F					
21.					
22. BURNER OUT OF SERVICE					
23.					
24. COMMENTS :	LOW NOx	LOW NOx	LOW NOx		
25.	LOW O_2				
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

UNIT OPERATING DATA **Test No.** A/4 - A/5

Test No. A/4 - A/5 **Date** 12-12-80 **Location** SITE # 6 **Engr.** TIPONA / HART

Unit No. H-53-A **Fuel** REFINERY GAS **Capacity** 20,000 BBL/DAY

Unit Type Crude Reformer Heater **Burner Type** LEA VENTURI

1. Test Number	A/4-1	A/4-2	A/4-3	A/5-1	A/5-2
2. Date	12-12-80	12-12-80	12-12-80	12-12-80	12-12-80
3. Time	09:20	09:35	10:45	11:20	12:05
4. Load					
5. Process Rate 10^3 BBL/HR	16	16	16	16	16
6. TOTAL FUEL TO 4 HTS. 10^3 [illegible]	4.1 (3280)	4.1 (3280)	4.1 (3250)	4.1 (3270)	4.0 (3210)
7. TEMP OUT (°F)	860	859	860	861	859
8. TEMP IN (°F)	750	750	750	752	753
9. O_2 HEATER %	3.5	4.0	3.5	5.1	6.1
10. NG FLOW N %	42.5	42	41.5	41.5	42
11. GAS P N (PSIG)	1.3	1.2	1.2	1.2	1.2
12. COMB AIR N %	46	46	46	50.5	58
13. NG FLOW S %	39.5	39.5	39	39	39
14. GAS P S (PSIG)	2.1	2.1	2.0	2.0	2.0
15. COMB AIR S %	53.5	53.5	52.5	58	58
16. TEMP FLUE GAS HEATER OUT °F	1315	1307	1312	1309	1303
17. TEMP FLUE GAS AH IN °F	598	598	597	597	595
18. TEMP FLUE GAS AH OUT °F	314	315	318	319	321
19. TEMP AMBEINT AH IN °F	516	516	517	516	515
20. TEMP AIR AH OUT °F					
21.					
22. BURNER OUT OF SERVICE					
23.					
24. COMMENTS :	BASELINE	BASELINE	BASELINE	LOW O_2	BASELINE
25.	(LOW O_2)				
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

UNIT OPERATING DATA

Test No. A/5

Test No. A/5 Date 12-12-80 Location SITE # C Engr. TIDONA / HART

Unit No. H-53-A Fuel REFINERY GAS Capacity 20,000 BBL/DAY

Unit Type Crude Reformer Heater Burner Type CEA VENTURI

1. Test Number	A/5-3	A/5-4	A/5-5		
2. Date	12-12-80	12-12-80	12-12-80		
3. Time	12:55	13:15	13:55		
4. Load					
5. Process Rate 10^3 BBL/DAY	16	16	16		
6. TOTAL FUEL TO 4 HTS. 10^6 BTU/H	4.0 (3200)	4.3 (3440)	4.3 (3440)		
7. TEMP OUT (°F)	857	855	862		
8. TEMP IN (°F)	750	746	750		
9. O_2 HEATER %	7.0	8.0	5.3		
10. NF FLOW N %	43	45.5	44		
11. GAS P N (PSIG)	1.4	1.5	1.2		
12. COMB AIR N %	62	72	51		
13. NF FLOW S %	40	43	42		
14. GAS P S (PSIG)	2.0	2.1	1.9		
15. COMB AIR S %	63	72	57		
16. TEMP FLUE GAS HEATER OUT °F	1301	1313	1308		
17. TEMP FLUE GAS AH IN °F	592	607	607		
18. TEMP FLUE GAS AH OUT °F	324	324	323		
19. TEMP AMBIENT AH IN °F	515	517	521		
20. TEMP AIR AH OUT °F					
21.					
22. BURNER OUT OF SERVICE					
23.					
24. COMMENTS:	MED.-HIGH O_2	HIGH O_2	LOW O_2		
25.					
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

Sample date: 12-8-80
Type for all tests, Site 6

REFINERY GAS ANALYSES FOR SITE #6

SPECIES	SITE #6 VOLUME %
CO_2	0.5
N_2 + CO	2.9
H_2	15.6
Methane	48.9
Ethylene	8.7
Ethane	14.0
Propylene	5.4
Propane	2.7
Butylene	0.3
Isobutane	0.4
Normal Butane	0.1
Pentanes	0.5
HHV, kJ/m^3 (Btu/ft^3)	43,183 (1159)

SITE 7

PETROLEUM PROCESS HEATER

Location No. SITE # 7 **Unit No.** 53B

Unit Description -Reformer Heater (Rectangular, Wall-Fired)
-Balanced Draft
-Preheated Combustion Air

Installation Date SEPTEMBER, 1980

Heater Rating 132 m^3/h (20,000 bbl/d)

Burner Description (8) CEA LOW-NO_x "VENTURI" BURNERS

Test Fuel Combinations REFINERY GAS

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) 520°

Comments:

B= SITE 7

MOBILE LABORATORY DATA

Test No. B/1

Test No. B/1 Date 12/16/80 Location ________ Engr. R.J. Tidona

Unit No. 53 B Fuel Refine. Gas Capacity ________

Unit Type ________ Burner Type C.E.A

1. Test No.	B/1-1		B/1-2		B/1-3		B/1-4		B/1-5	
2. Date 12/16/80										
3. Time	0935		1050		1125		1205		1355	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	5.3		4.1		3.0		2.6		4.2	
9. NOx (hot) read/3% O_2 (ppm)*	/		/		/		/		/	
10. NO (hot) read/3% O_2 (ppm)*										
11. NO_2 (hot) read/3% O_2 (ppm)*										
12. NO (cold) read/3% O_2 (ppm)*	113	130	105	112	86	86	88	86	110	118
13. Carbon Dioxide (%)	9.4		10.8		10.0		10.2		10.0	
14. Carbon Monoxide (ppm) uncor/cor*	10	11	20	21	20	20	30	29	20	21
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-	0	-	5	-	0	-
16. Sulfur Dioxide (ppm) uncor/cor*	14	-	12	-	14	-	12	-	12	-
17. Smoke Spot (Bacharach)	-		-		-		-		-	
18. Atmos. Temp. (°F/°C)	44°		48°		50°		60°		62°	
19. Dew Point Temp. (°F/°C)	43		46°		47°		53°		55°	
20. Atmos. Pressure (in. Hg)	30.16		30.16		30.15		30.10		30.10	
21. Relative Humidity (%)	92%		86%		80%		62%		65%	
22.									Base Line Repeat	
23.										
24.										
25.	As found									
26.			Base Line		Low O_2		Min. O_2			
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

B= SITE 7

MOBILE LABORATORY DATA

Test No. B/2

Test No. B/2 Date 12/16/80 Location________ Engr. R.J. Tidona

Unit No. 53 B Fuel Refin. Gas Capacity________

Unit Type________ Burner Type CEA

1. Test No. B/2	B/2-1		B/2-2				
2. Date	12/16/80		12/16/80				
3. Time	1550		1645				
4. Load							
5. Process Rate							
6. Flue Diam. or Size, ft							
7. Probe Position Center							
8. Oxygen (%)	4.0		2.3				
9. NOx (hot) read/3% O_2 (ppm)*	74	-	62	-			
10. NO (hot) read/3% O_2 (ppm)*	72	-	59	-			
11. NO_2 (hot) read/3% O_2 (ppm)*	2	-	3	-			
12. NO (cold) read/3% O_2 (ppm)*	93	98	73	70			
13. Carbon Dioxide (%)	9.2		10.4				
14. Carbon Monoxide (ppm) uncor/cor*	30	31	35	33			
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-			
16. Sulfur Dioxide (ppm) uncor/cor*	10	-	15	-			
17. Smoke Spot (Bacharach)	-		-				
18. Atmos. Temp. (°F/°C)	62°		59°				
19. Dew Point Temp. (°F/°C)	55		54°				
20. Atmos. Pressure (in. Hg)	30.06		30.05				
21. Relative Humidity (%)	64%		72%				
22.							
23.	Bias Combustion Air /4.0 O_2						
24.							
25.							
26.							
27.							
28.							
29.							
30.							

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

UNIT OPERATING DATA

Test No: B/1

Test No. B/1 **Date** 12-16-80 **Location** ______ **Engr.** Tidona

Unit No. H-53B **Fuel** Ref. Gas **Capacity** 20000 bbl/day

Unit Type Crude Reformer Heater **Burner Type** CEA Venturi

1. Test Number	B/1-1	B/1-2	B/1-3	B/1-4	B/1-5
2. Date	12-16-80	12-16-80	12-16-80	12-16-80	12-16-80
3. Time	09:35	10:48	11:25	12:04	12:58
4. ~~Load~~					
5. Process Rate 10^3 bbl/d ×2.3	6.3 ×2.3 = 14.5	(6.2) 14.3	(6.3) 14.5	6.2 14.3	6.2) 14.3
6. Fuel to 4 htrs crude oil 10^3 ft^3/d ×800	4.1×800 = 3280	4.2 3360	4.25 3400	4.2 3360	4.15 3320
7. T out process °F / TC #19	860	864	866	873	868
8. T in process °F / TC #15	726	727	728	730	730
9. Excess O_2 % -	4.0	3.1	2.5	2.2	3.0
10. Fuel Gas Flow N %	45	45.5	46.5	44.5	45
11. " " P N psig	2.0	2.0	2.0	2.5	1.7
12. Comb. Air N Flow %	46	45.5	46	45	46.5
13. Fuel Gas Flow S %	44.5	44.5	45	44.5	45
14. " " P S psig	2.0	2.1	2.0	2.0	2.0
15. Comb. Air S Flow %	44	44.5	44.5	44.5	45
16. TC 34 Flue Gas Htr Out	1336°F	1345	1368	1374	1343
17. TC 37 Flue Gas AH In, °F	606	605	605	602	602
18. TC 32 " " " Out °F	313	315	316	319	321
19. TC 29 Air AH out, °F	516	517	516	517	517
20. T ambient Air AH in, °F	44	47	50	60	62
21. Fuel Gas Flowmeter Press. psig	22.5	22	22	21.5	22.5
22. BOOS	NONE	NONE	NONE	NONE	NONE
23. Fuel Gas to Reboiler 10^3 scfd	565	568	570 →	568	575
24.					
25. Comments:	As FOUND	BASELINE	3% O_2	MIN O_2	REPEAT
26.	HEATER 53B	~4% O_2	flames getting	Starting setting	BASELINE
27.			long, lazy,	off control rm.	
28.			smoky, & yellow	alarm for	
29.				low air	
30.					

Data Sheet 6002-1

UNIT OPERATING DATA **Test No:** B/2

Test No. B/2 **Date** 12-16-80 **Location** **Engr.** Ti Lone

Unit No. H-53B **Fuel** Ref. Gas **Capacity** 20 000 bbl/day

Unit Type Crude Reformer Heater **Burner Type** CEA Venturi

1. Test Number	B/2-1	B/2-2			
2. Date	12-16-80	12-16-80			
3. Time	15:50	16:47			
4. ~~Load~~					
5. Process Rate 10^3 bbl/d	6.3 14.5	6.2 14.3			
6. Fuel to 4 htrs. 10^6 ft^3/d X400	4.0 3200 X400	4.1 3280 X400			
7. T_{out} process °F / TC # 14	874	873			
8. T_{in} process °F / TC # 15	738	734			
9. Excess O_2 % -	3.2	1.8			
10. Fuel Gas Flow N %	46	45.5			
11. " " P N psig	1.8	1.6			
12. Comb. Air N Flow %	45	36.5			
13. Fuel Gas Flow S %	44.5	45			
14. " " P S psig	2.0	2.0			
15. Comb. Air S Flow %	36.5	31.5			
16. TC $\frac{34}{33}$/ Flue Gas Htr. OUT	1355	1367			
17. TC 37 Flue Gas AH In	599	596			
18. TC 32 " " " Out	324	322			
19. TC 29 Air AH out	516	514			
20. T ambient Air AH in	62	58			
21. Fuel Gas Flowmeter Press psig	22	21			
22. 800S	NONE	NONE			
23. Fuel Gas to Reboiler, 10^3 scfd	578	570			
24.					
25. Comments:	low air S	bias firing			
26.	high air N	+ low O_2			
27.	~4% O_2	#4 burner			
28.	south brnrs.	on S side			
29.	little sooty, yellow	unstable; others same			
30.	north OK	as in B/2-1			

Data Sheet 6002-1

Sample date: 12-16-80
Type for all tests, Sites 7-10

REFINERY GAS ANALYSES FOR SITES #7-10

SPECIES	SITE #7-10 VOLUME %
CO_2	0.4
N_2 + CO	3.3
H_2	18.8
Methane	50.1
Ethylene	8.2
Ethane	13.0
Propylene	3.1
Propane	1.6
Butylene	0.6
Isobutane	0.3
Normal Butane	0.2
Pentanes	0.4
HHV, kJ/m^3 (Btu/ft^3)	40,202 (1079)

SITE 8

PETROLEUM PROCESS HEATER

Location No. SITE # 8 Unit No. 53C

Unit Description -Reformer Heater (Rectangular, Wall-Fired)
-Balanced Draft
-Preheated Combustion Air

Installation Date SEPTEMBER, 1980

Heater Rating 132 m^3/h (20,000 bbl/d)

Burner Description (8) CEA LOW-NO_x "VENTURI" BURNERS

Test Fuel Combinations REFINERY GAS

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) 520°

Comments:

C = SITE 8

MOBILE LABORATORY DATA

Test No. C/1

Test No. C/1-1 Date 12/17/80 Location________ Engr. R. Tidona

Unit No. 53 C Fuel Refin. Gas Capacity________

Unit Type________ Burner Type C.E.A.

1. Test No. C/1	C/1-1		C/1-2		C/1-3		C/1-4			
2. Date 12/17/80										
3. Time	1035		1145		1245		1305			
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	7.7		5.1		3.8		5.1			
9. NOx (hot) read/3% O_2 (ppm)*	93	-	69	-	62	-	73	-		
10. NO (hot) read/3% O_2 (ppm)*	90	-	68	-	59	-	70	-		
11. NO_2 (hot) read/3% O_2 (ppm)*	3	-	1	-	3	-	3	-		
12. NO (cold) read/3% O_2 (ppm)*	109	148	87	98	77	81	88	100		
13. Carbon Dioxide (%)	6.9		9.1		10.2		9.6			
14. Carbon Monoxide (ppm) uncor/cor*	10	14	12	14	14	15	14	16		
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-	0	-	0	-		
16. Sulfur Dioxide (ppm) uncor/cor*	12	-	17	-	18	-	14	-		
17. Smoke Spot (Bacharach)	-		-		-		-			
18. Atmos. Temp. (°F/°C)	62°		62°		63°		63°			
19. Dew Point Temp. (°F/°C)	55°		55°		56°		56°			
20. Atmos. Pressure (in. Hg)	30.05		30.05		30.02		30.02			
21. Relative Humidity (%)	64%		64%		64%		64%			
22.	As Found		Base Line Cond.		Min. O_2* Lower Air South Side		5% O_2 Lower Air South Side			
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

C= SITE 8

UNIT OPERATING DATA

Test No: C/1

Test No. C/1 **Date** 12-17-80 **Location** ________ **Engr.** Tidona

Unit No. H-53 **Fuel** Ref. Gas **Capacity** 20000 bbl/day

Unit Type Crude Reformer Heater **Burner Type** CEA Venturi

1. Test Number	C/1-1	C/1-2	C/1. 3	C/1-4	
2. Date	12-17-80	12-17-80	12-17-80	12-17-80	
3. Time	10:32	11:50	12:46	13:07	
4. ~~Load~~					
5. Process Rate 10^3 bbl/d	6.5 15.0	6.4 14.7	6.5 15.0	6.1 14.0	
6. Fuel to 4 htrs 10^3 ft³/d	4.1 3280	4.1 3280	4.05 3240	4.0 3200	
7. Tout process °F / TC #24	862	859	864	864	
8. Tin process °F / TC #40	783	777	779	782	
9. Excess O_2 % -	8.0	4.5	3.5	4.5	
10. Fuel Gas Flow N %	38	36.5	39	39	
11. " " P N psig	1.2	1.0	1.3	1.3	
12. Comb. Air N Flow %	46	39.5	38	46.5	
13. Fuel Gas Flow S %	36.5	36	35	34.5	
14. " " P S psig	1.2	0.9	0.9	0.9	
15. Comb. Air S Flow %	54.5	41.5	31.5	36.5	
16. TC 35/33 Flue Gas Htr OUT	1265 °F	1308	1327	1312	
17. TC 37 Flue Gas AH In, °F	603	589	592	591	
18. TC 32 " " " Out, °F	319	322	327	327	
19. TC 39 Air AH out, °F	516	514	515	515	
20. T ambient Air AH in, °F	62	62	63	63	
21. Fuel Gas Flowmeter Press., psig	22	21	23	22	
22. BOOS	NONE	NONE	NONE	NONE	
23. Fuel Gas to Reboiler, 10^3 scfd	572	570	580	580	
24.					
25. Comments:	As FOUND	BASELINE	MIN O_2	5% O_2	
26.	~8% O_2	~5.1% O_2	lower air to S	lower air	
27.			side	to S side	
28.					
29.					
30.					

Data Sheet 6002-1

Sample date: 12-16-80
Type for all tests, Sites 7-10

REFINERY GAS ANALYSES FOR SITES #7-10

SPECIES	SITE #7-10 VOLUME %
CO_2	0.4
N_2 + CO	3.3
H_2	18.8
Methane	50.1
Ethylene	8.2
Ethane	13.0
Propylene	3.1
Propane	1.6
Butylene	0.6
Isobutane	0.3
Normal Butane	0.2
Pentanes	0.4
HHV, kJ/m^3 (Btu/ft^3)	40,202 (1079)

SITE 9

PETROLEUM PROCESS HEATER

Location No. SITE # 9 Unit No. 53D

Unit Description -Reformer Heater (Rectangular, Wall-Fired)
-Balanced Draft
-Preheated Combustion Air

Installation Date SEPTEMBER, 1980

Heater Rating 132 m^3/h (20,000 bbl/d)

Burner Description (8) CEA LOW-NO_x "VENTURI" BURNERS

Test Fuel Combinations REFINERY GAS

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) 520°

Comments:

D = SITE 9

MOBILE LABORATORY DATA

Test No. D/1

Test No. D/1 Date 12/17/80 Location ______ Engr. R. Tidona

Unit No. 53 D Fuel Refinery Gas Capacity ______

Unit Type ______ Burner Type C. E. A.

1. Test No. D/1	D/1-1		D/1-2		D/1-3		D/1-4		D/1-5	
2. Date 12/17/80										
3. Time	1450		1530		1555		1615		1645	
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	6.2		4.0		3.3		4.2		3.8	
9. NOx (hot) read/3% O_2 (ppm)*	75	-	57	-	53	-	54	-	53	-
10. NO (hot) read/3% O_2 (ppm)*	73	-	56	-	52	-	53	-	53	-
11. NO_2 (hot) read/3% O_2 (ppm)*	2	-	1	-	1	-	1	-	0	-
12. NO (cold) read/3% O_2 (ppm)*	98	119	71	75	64	65	68	73	68	71
13. Carbon Dioxide (%)	8.4%		10.0%		10.2%		9.9%		9.9%	
14. Carbon Monoxide (ppm) uncor/cor*	0	0	10	11	10	10	10	11	12	13
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-	0	-	0	-	0	-
16. Sulfur Dioxide (ppm) uncor/cor*	12	-	10	-	8	-	8	-	12	-
17. Smoke Spot (Bacharach)	-		-		-		-		-	
18. Atmos. Temp. (°F/°C)	65°		65°		60°		59°		59°	
19. Dew Point Temp. (°F/°C)	57°		57°		55°		55°		54°	
20. Atmos. Pressure (in. Hg)	30.00		29.98		29.98		29.98		29.98	
21. Relative Humidity (%)	57%		57%		73%		77%		72%	
22.							Low Air North Side			
23.										
24.								approx 4.0% O_2		
25.	As Found									
26.			Base Line							
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

MOBILE LABORATORY DATA

Test No. D/1

Test No. D/1 Date 12/17/80 Location ______ Engr. R. Tidona

Unit No. 53 B Fuel Refinery Gas Capacity ______

Unit Type ______ Burner Type C.E.A

1. Test No.	D/1-6									
2. Date	12/17/80									
3. Time	1700									
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position	Center									
8. Oxygen (%)	6.3									
9. NOx (hot) read/3% O_2 (ppm)*	76	-								
10. NO (hot) read/3% O_2 (ppm)*	73	-								
11. NO_2 (hot) read/3% O_2 (ppm)*	3	-								
12. NO (cold) read/3% O_2 (ppm)*	92	114								
13. Carbon Dioxide (%)	8.1%									
14. Carbon Monoxide (ppm) uncor/cor*	10	12								
15. Hydrocarbon (ppm) uncor/cor*	0	-								
16. Sulfur Dioxide (ppm) uncor/cor*	10	-								
17. Smoke Spot (Bacharach)	-									
18. Atmos. Temp. (°F/°C)	59°									
19. Dew Point Temp. (°F/°C)	55°									
20. Atmos. Pressure (in. Hg)	29.98									
21. Relative Humidity (%)	77%									
22.										
23.										
24.										
25.										
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

D=SITE 9

UNIT OPERATING DATA **Test No:** D/1

Test No. D/1 **Date** 12-17-80 **Location** ______ **Engr.** Tidona

Unit No. H-53 **Fuel** Ref. Gas **Capacity** 20 000 bbl/day

Unit Type Crude Reformer Heater **Burner Type** CEA Venturi

1. Test Number	D/1-1	D/1-2	D/1-3	D/1-4	D/1-5
2. Date	12-17-80	12-17-80	12-17-80	12-17-80	12-17-80
3. Time	14:52	15:30	16:00	16:16	16:45
4. ~~Load~~					
5. Process Rate 10^3 bbl/d	6.4 14.7	6.1 14.0	6.3 14.5	6.4 14.7	6.4 14.7
6. Fuel to 4 htrs 10^3 ft³/d	4.4 3520	4.3 3440	4.2 3360	4.2 3360	4.2 3360
7. Tout process °F / TC #27	862	863	862	863	864
8. Tin process °F / TC #25	803	803	803	804	805
9. Excess O₂ % -	5.7	3.5	3.3	3.7	3.6
10. Fuel Gas Flow, N %	37	32.5	32.5	32.5	32.5
11. " " P N psig	0.5	0.6	0.6	0.7	0.8
12. Comb. Air N Flow %	37.5	33.5	36	38.5	34
13. Fuel Gas Flow S %	37	34.5	34.5	34	34
14. " " P S psig	1.0	1.0	0.9	0.9	0.9
15. Comb. Air S Flow %	38	34.5	40.5	46	37.5
16. TC ~~33~~ 36 Flue Gas Htr OUT	1343	1344	1350	1343	1348
17. TC 37 Flue Gas AH In	607	606	606	605	604
18. TC 32 " " " Out	322	322	319	320	320
19. TC 39 Air AH out	518	519	518	518	518
20. T ambient Air AH in	65	65	60	59	59
21. Fuel Gas Flowmeter Press, psig	20	22	22.5	22.5	22
22. BOOS	NONE	NONE	NONE	NONE	NONE
23. Fuel Gas to Reboiler, 10^3 scfd	570	580	580	580	580
24.					
25. Comments:	AS FOUND	BASELINE	MIN O₂	4.2% O₂	3.8% O₂
26.		~4% O₂		low air to	low air to
27.				N side	N side
28.					
29.					
30.					

Data Sheet 6002-1

UNIT OPERATING DATA

Test No: D/1

Test No.________ **Date** 12-17-80 **Location**________ **Engr.** Tidona

Unit No. H-53 **Fuel** Ref. Gas **Capacity** 20000 bbl/day

Unit Type Crude Reformer Heater **Burner Type** CEA Venturi

1. Test Number	D/1-6				
2. Date	12-17-80				
3. Time	17:02				
4. ~~Load~~					
5. Process Rate 10^3 bbl/d	6.15 14.1				
6. Fuel to 4 htrs 10^3 ft^3/h	4.2 3360				
7. T out process °F / TC #29	858				
8. T in process °F / TC #25	901				
9. Excess O2 % -	5.9				
10. Fuel Gas Flow, N %	33				
11. " " P N psig	0.8				
12. Comb. Air N Flow %	48.5				
13. Fuel Gas Flow S %	34				
14. " " P S psig	0.8				
15. Comb. Air S Flow %	48				
16. TC ~~33~~ 36 Flue Gas Htr OUT	1317				
17. TC 37 Flue Gas AH In	604				
18. TC 32 " " " Out	323				
19. TC 39 Air AH out	517				
20. T ambient Air AH in	59				
21. Fuel Gas Flowmeter Press, psig	21.5				
22. BOOS	NONE				
23. Fuel Gas to Reboiler, 10^3 scfd	578				
24.					
25. Comments:	High O_2				
26.					
27.					
28.					
29.					
30.					

Data Sheet 6002-1

Sample date: 12-16-80
Type for all tests, Sites 7-10

REFINERY GAS ANALYSES FOR SITES #7-10

SPECIES	SITE #7-10 VOLUME %
CO_2	0.4
N_2 + CO	3.3
H_2	18.8
Methane	50.1
Ethylene	8.2
Ethane	13.0
Propylene	3.1
Propane	1.6
Butylene	0.6
Isobutane	0.3
Normal Butane	0.2
Pentanes	0.4
HHV, kJ/m^3 (Btu/ft^3)	40,202 (1079)

SITE 10

PETROLEUM PROCESS HEATER

Location No. 10 **Unit No.** —

Unit Description - DEBUTANIZER BOTTOMS REBOILER (VERTICAL CYLINDRICAL RADIANT SECTION AND RECTANGULAR CONVECTION SECTION)
- FORCED DRAFT
- AMBIENT COMBUSTION AIR

Installation Date SEPTEMBER, 1980

Heater Rating 197 m^3/h (29,672 bbl/d)

Burner Description (1) CEA LOW-NO_x VENTURI BURNER

Test Fuel Combinations REFINERY GAS

Fuel Temp. at Burner (°F) AMBIENT

Primary Air Temp. (°F) AMBIENT

Comments:

MOBILE LABORATORY DATA

Test No. 10/1-1

Test No. 10/1-1 Date 12/18/80 Location__________ Engr. R. Tidona

Unit No.________ Fuel Refinery Gas Capacity__________

Unit Type__________ Burner Type CEA (Vertical)

1. Test No.	10/1-1		10/1-2		10/1-3		10/1-4			
2. Date 12/18/80										
3. Time	1300		1450		1510		1525			
4. Load										
5. Process Rate										
6. Flue Diam. or Size, ft										
7. Probe Position Center										
8. Oxygen (%)	6.7		3.8		1.8		2.8			
9. NOx (hot) read/3% O2 (ppm)*	73	-	65	-	47	-	59	-		
10. NO (hot) read/3% O2 (ppm)*	70	-	63	-	46	-	52	-		
11. NO2 (hot) read/3% O2 (ppm)*	3	-	2	-	1	-	1	-		
12. NO (cold) read/3% O2 (ppm)*	81	102	78	82	54	51	66	65		
13. Carbon Dioxide (%)	8.0%		10.2		11.2		10.9			
14. Carbon Monoxide (ppm) uncor/cor*	10	13	10	10	160	150	10	10		
15. Hydrocarbon (ppm) uncor/cor*	0	-	0	-	0	-	0	-		
16. Sulfur Dioxide (ppm) uncor/cor*	8	-	10	-	12	-	10	-		
17. Smoke Spot (Bacharach)	-		-		-		-			
18. Atmos. Temp. (°F/°C)	63°		63°		62°		61°			
19. Dew Point Temp. (°F/°C)	58°		57°		57		55°			
20. Atmos. Pressure (in. Hg)	30.09		30.08		30.08		30.08			
21. Relative Humidity (%)	74%		69%		73%		70			
22.										
23.										
24.										
25.	As Found		Baseline		CO Limit					
26.										
27.										
28.										
29.										
30.										

*Correction to 3% O_2 should not be performed if the value is measured on a wet basis.

Data Sheet 6002-2

$240{,}000 \text{ scfd} \cdot \sqrt{\frac{P}{T \cdot G}} \cdot rdg = Q(\text{scfd})$

$0 < rdg < 10$

UNIT OPERATING DATA

Test No.

Test No. Date 12-18-80 Location Engr. Tidona

Unit No. Fuel Refinery Gas Capacity

Unit Type Debutanizer Bottoms Reboiler Burner Type CEA LOW-NO$_x$

1. Test Number	10/1-1	10/1-2	10/1-3	10/1-4	
2. Date	12-18-80	12-18-80	12-18-80	12-18-80	
3. Time	13:03	14:56	15:12	15:25	
4. Load					
5. Debut. Bottoms to Reblr. Process Rate (total) 10³ lb/h	28.3	28.3	28.3	28.3	
6. Fuel gas to Reblr., 10³ scfd	580	580	590	578	
7. Fuel gas Flowmeter Press, psig	22	22.5	22.5	21.5	
8. Platformate to Storage, ×2.3 10³ bbl/d	(6.4) 14.7	(6.3) 14.2	(6.6) 15.2	(6.2) 15.2	
9. T$_{out}$ Process, °F	513	514	516	518	
10. Control Rm. O$_2$, %	6.25	3.2	0.35	1.25	
11. Fuel Gas Flow Guage	33	33	33	32.5	
12. Combustion Air Flow to Rblr., rdg	55	50	40	45	
13. T$_{in}$ Process, °F	458	457	458	461	
14. T$_{radiant}$ (Flue gas), °F	1163	1210	1235	1219	
15. T$_{conv.}$ (Flue gas), °F	486	525	520	519	
16. Comb. air Temp., °F	63	63	62	62	
17. Furnace Draft, in. H$_2$O	1.3	1.2	1.0	1.1	
18.					
19.					
20.					
21.					
22.					
23.					
24. Comments	As Found	BASELINE	CO LIMIT	MED. LO O$_2$	
25.				flame looks	
26.				good. ~8' tall	
27.				blue at bottom 1' or 2' and yellow	
28.				above. Swirl	
29.					
30.					

Data Sheet 6002-1

Sample date: 12-16-80
Type for all tests, Sites 7-10

REFINERY GAS ANALYSES FOR SITES #7-10

SPECIES	SITE #7-10 VOLUME %
CO_2	0.4
N_2 + CO	3.3
H_2	18.8
Methane	50.1
Ethylene	8.2
Ethane	13.0
Propylene	3.1
Propane	1.6
Butylene	0.6
Isobutane	0.3
Normal Butane	0.2
Pentanes	0.4
HHV, kJ/m^3 (Btu/ft^3)	40,202 (1079)